NPS-IJWA-01-002

ETHNOGRAPHIC QUALITATIVE KNOWLEDGE MANAGEMENT SYSTEM DATA CLASSIFICATION SCHEMA

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This report was prepared for and funded by:
Institute for Joint Warfare Analysis,
Joint Experimentation command and Office
of Naval Research under the CDTEMS program

This report was prepared by:

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY	2. REPORT DATE Jun 2000	3. REPORT TYPE AND DATES COVERED Technical 1 Oct 98 - 1 May 00

4. TITLE AND SUBTITLE Ethnographic Qualitative Knowledge Management System Data Classification Scheme	5. FUNDING NUMBERS ONR # N0001400WR20307
6. AUTHOR(S) R. William Maule, et. al.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Joint Warfare Analysis Naval Postgraduate School Monterey, CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER NPS-IJWA-01-002
9. SPONSORING/MONITORING AGENCY(s) Office of Naval Researchh and Joint Experimentation Command through the CDTEMS project and Institute for Joint Warfare Analysis	10. SPONSORING/MONITORING AGENCY REPORT NUMBER None

The views expressed in this report are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government

12A. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited	

13. ABSTRACT (maximum 200 words)

A knowledge management system has been developed to archive and retreive information that is developed during Fleet Battle Experiments. This system utilizes Ethnograph as the knowledge engine. The data are both subjective and objective, from a wide variety of sources. A data tagging scheme is used that maps onto the logical functions performed during flet operations. Tags are also used that capture context information. The tags are used to create data retreival "threads" to address specific initiative, process, and system questions.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Knowledge Management Databases	46
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

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IJWA EQKMS Data Classification Schema

1.0 Introduction

The discipline of Knowledge Management (KM) is new but emerging rapidly in the commercial, industrial and government sectors of the economy where there is a need for insight on consumer-business, business-business, and agency-agency decisions. The situation in the military is several layers of complexity beyond the consumer market and must address not only mission-critical data but do so within the scope of an extremely dynamic environment. Corporations build knowledge management systems to understand overall market trends that might affect the company over the next several quarters. Military systems are far more complex, managing knowledge from many more sources—with data streams from a variety of technologies, input from divergent perspectives, and very short time frames in which to make critical decisions.

To support the needs of the military, IJWA is categorizing information within a knowledge repository. IJWA collects both qualitative and quantitative data in their support of FBEs. The IJWA Ethnographic Qualitative Knowledge Management System (EQKMS) is a repository for reports, interviews, chats, observations, and other FBE qualitative information. The first sections of this report address the qualitative knowledge management processes under development through the EQKMS project and the later sections discuss the relationship between qualitative and quantitative data schemas, integration methodologies for FBE data, and present and future capabilities.

2.0 KM for Analysis of Operational Capabilities

The term "Knowledge Management" is used here in the broadest sense. We refer to managing numerical values obtained from an automated collection system, human subjective opinions, synthesis results, results tailored to address specific long-range initiatives, etc. The challenge is to create a knowledge management, KM, system that enables archival, retrieval, and analysis. This paper describes a KM system that supports the analysis of military capabilities.

The information to be archived in this system come from differing sources: studies, wargames, and field experiments. A characteristic of these events is their variability. They have neither a common structure nor a common core of assumptions. In fact, there is an overt desire to test a range of operational structures and situations so that even a given type of event, such as Fleet Battle Experiments, will have some of its conditions change from event to event. On the other hand, there is a desire to synthesize results from many events to obtain conclusions on current and future operational capabilities. This means that the KM system must be robust to changes in the configurations under which information is obtained and developed.

The most important step in creating the KM system is to insure that it supports the major strategic, operational, and tactical questions being addressed, or that may later be addressed, by the events. The KM system described here has been created specifically for Fleet Battle Experiments. Fortunately, Fleet Battle Experiments are very broad in configuration and the issues they address so it has been relatively easy, using them as a model, to develop the required KM system.

Within DoD, there are a relatively small number of overarching concepts under consideration. For a high-level organizing structure, we use concepts such as:

Joint Maritime Access Control (JMAC)
Time Critical Targeting (TCT)
Theater Ballistic Missile Defense (TBMD)
Full Dimension Protection (FDP)
Mine Counter Measures (MCM)
Network Centric Warfare (NCW)
Common Operations Picture (COP)

These are an illustration, not an all-inclusive list. They are important operational concepts that support multilevel questions, including high-level questions such as "should we operate in the littoral?", "can we support widely dispersed troops ashore?".

Examining the above list, one sees immediately that the concepts are not independent nor are they of the same type. JMAC is a strategic goal and TCT, TBMD, FDP, and MCM are operations needed in support of that goal. NCW is an information superiority concept which can aid or enable operations rather than a type of operation. COP is a needed tool within NCW. Even though there are structural differences between these "concepts", they are often treated as being at the same level when planning a complex event. This is not a problem as long as one recognizes the differences and sets up a KM structure which allows the proper relationships between them when analyzing the events.

Developing a KM system requires that there be an archiving methodology which supports the "thread pulling" method used for developing and retrieving information. When archiving we place several appropriate "tags" on each piece of data. (We are using the term "data" very broadly here). Information is retrieved by "pulling" on a set of tags, which we refer to as thread analysis. Thread analysis starts with a specific question, from which a set of tags is defined to pull the appropriate data. The data archive must be as robust as possible with respect to thread analysis for a wide range of questions, i.e., the system must be set up so that one can access every piece of data that has applicability to a given area of inquiry. This requires an extensive set of tags and several tags on each datum. If the tagging system is not set up wisely, the number of tags needed on a particular datum can get out of hand. We have found that the answer to this dilemma of the need to balance robustness and cumbersome tagging is to take an object oriented approach, which is described later in this document.

Knowledge, information, data, regardless of the semantics used, occur in a hierarchy or at levels. There are no hard and fast rules for the number of levels and how they are defined. The number depends on the granularity desired for information. The definition depends on the specifics of the system being examined. In general, too many levels (fine grained) leads to an overly complex KM system which is arduous and time consuming to use.

For our purposes, we prefer three levels. They are:

Level-1 - objective and subjective data that directly address events (event data).
Level-2 - conclusions concerning the performance of a system (system information).

Level-3 - conclusions that address capabilities at the initiative level (results).

Note that we are now discriminating between the terms data, information, and results.

> Level-1 data consists of event descriptions and the time at which events occur. Data can be obtained from an automated acquisition system or from an observer recording an occurrence. Data also includes observations of the status of systems, work-arounds, configuration changes, etc. that occur at a particular time.
>
> Level-2 information often is a subjective opinion, but it can also be a conclusion developed from Level-1 data. There is no time associated with them but they should be in the "context" of a particular operation, platform, command and control configuration, etc. These contexts can change with time. Context information is often referred to as "meta-data". As noted above, Level-2 data refers to systems. "System" is not meant to apply only to hardware. It often will refer to a C2 system, and can also refer to a process. The only requirements for something to be called a system are that it be an identifiable entity and that the interrelationships between its components can be defined. One must also be able to identify the interactions between the system and its external world.
>
> Level-3 results will most often be pulled from Levels 1 and 2 through thread analysis. Expert opinion may also be directly inputted to the KM system database. When this is done, developing supporting information from Levels 1 and 2 should be done or the validity of the results may be suspect.

It is important to recognize that questions have levels in order to couple questions to the proper thread-pulling analysis from the KM system. Question levels are not the same as data levels, and the answer to a given question will usually require accessing more than one KM level. Examples most easily illustrate this. Consider two questions:

1. Does a particular system (or method) shorten the TCT time line.
2. Does a particular COP configuration aid in reducing the TCT time line.

The first question is straightforward, and the answer requires pulling the appropriate Level-1 data, in particular the times required to perform the various TCT processes. One requirement is that there be a performance baseline from which the comparison can be made if sense is to be made of "shorten". The second question is more complex. Answering it can require that one pull data and information from Levels-1 and -2, then attempt to isolate the influence of the COP from other factors. The answers to these questions can provide KM system information and results at Levels-2 and -3.

2.1 Question, Data-level, And System Relationships

The purpose of the KM system is to support analysis of operational capabilities through the examination of processes and systems. Questions form the basis for analysis and are the key to reaching into the KM system. Information may be desired about a system that provides an end-to-end capability, or one of its subsystems. The question could concern the effectiveness of task performance, perhaps using an MOE such as time, or it could be the value of a particular parameter, such as reliability. One must devise the three-level KM system, and the associated data tags, so that a wide diversity of questions can be supported.

The relationships between and within KM system levels are important. A systematic methodology is needed to aggregate data in Level-1 into information for Level-2. There must be coherence between opinions inserted directly into Level-2 and the information pulled from Level-1. The same is true for the relationships between Level-2 information and Level-3 results.

Tags placed on information and data are the keys to accessing them. The analysis methodology that allows one to go from a question to the correct set of keys to obtain the desired answer must be logical, reasonably transparent, and fairly easy to use. The basic requirements for a viable data tagging scheme are:

- an easy correspondence between questions addressed to a particular KM level and the tags
- a logical relationship between the tags for the three levels

The relationships between the types of questions and the three KM Levels are fairly straightforward when one refers to the definition of the Levels given above. Where the various types of system information can be found and how that relates to questions is more complex. To illustrate we consider possible questions that address the two Levels. First, two Level-1 system questions:

a. How long does it take from detection of a time critical target to the time when weapon/target pairing is completed?
b. How long does it take to perform target mensuration?

Both are Level-1 questions because they refer to the value of a particular system parameter, time for both questions. The first time can be obtained by summing the processing times for the appropriate parts of the total system. It may be necessary to follow sets of events through the system to obtain the times, or the processing times may be archived. The second time is obtained by pulling data for the subsystem that performs mensuration.

Second, consider two Level-2 questions:

a. Does incorporation of an ISR desk to manage sensors improve the TCT process?
b. Does an ISR desk improve the quality of forwarded target folders?

Both are Level-2 questions because they do not ask for a parameter or MOE, but for information about system performance. The first question concerns a macro-process, TCT, and the second for a sub-process, target folders generation.

It may be that the answers to the Level-2 questions can be obtained by reaching into only information in Level-2 or it may be necessary to also pull out some Level-1 data. Note that both questions contain the word "improve". This implies that a comparison is needed between performing a process with and without and ISR desk, which means that somewhere there must be baseline, or without the desk, information. This means that information, or tags, must be present in the KM system that identifies the configurations that were in use when data/information were collected. The above examples illustrate that a fair amount of care is needed to relate questions and the tags.

The fact that Level-2 data will contain subjective system information implies that the information will not make sense unless one has a good definition of what the system is. This is true, and especially important for C2I systems because they are in a near-continuous state of evolution. Thus, maps of the various C2I systems are required as supporting information for the data archive (accessed through tags on the data and information). In addition, there are many hardware and software differences between experiments, so that supporting configuration information and tags must also be included.

2.2 Data Tagging Structure

The tagging structure must map in a fairly transparent way on the objects and events that make up military operations. The number of categories should be small to reduce complexity, and there should be no overlapping categories, which would create uncertainty in how to tag and make information retrieval difficult. These criteria can be accomplished by defining three categories:

Things – objects, systems, or people that perform actions.
Attributes – descriptions of the state or characteristics of things.
Actions – activities that occurs at a particular time that change the state of a thing or are interactions between things.

There are subtleties involved in using a simplified tagging structure of this type. For example, suppose the piece of information to be archived is an action taken by an object. The obvious tags are those that identify the object and the action taken. In addition, it is probably important to know the attributes of the object to place the information in the proper context. Thus tags from all three categories can be needed for the datum. Almost never will data be tagged with only one of the above categories.

Things	Attributes	Actions
Platform	Status	Transmit
Sensor	Mission	Receive
Weapon	Location	Detect
Information	Cmd Relation	Decide
C2 System	Assignment	Command
Force		Fire
Cmd Center		Reposition

Figure 1. Level 1 objective and subjective data that directly address events.

Within these three categories it is possible to identify the sets of Things, Attributes, and Actions that will adequately describe military operations (Figure 1).

Some of these are obvious, some not, and examination of the lists could lead one to conclude some are downright strange. A full description of the underlying rationale is beyond the scope of this paper, but a few examples to illustrate the basic ideas are warranted.

C2 system refers to the full system.
Command Node is an activity that issues commands, be it a single person or CIC.
Physical refers to any physical action, such as fire or reposition.
Command is the issuance of a command at its source.
Transmit refers to sending any information, including commands.
A force is any size grouping of platforms.
Workload refers to how much activity a thing has to perform.
Capacity is the current ability to carry out its activity.
Capacity can also be physical, such as how many rounds in a magazine.

Obviously, there are many sub-tags within each of these descriptors. There are types and identifiers, e.g., platform includes a tag for the type, such as ship or airplane and the identification of the specific platform. Decide could be a decision to engage a target or it could be a decision made for BDA assessment. Data and information will have tags that identify where they fit within these categories. A given piece of data will have more than one tag, e.g. to tag sensor information being sent: sensor, platform, sensor type, location, sensor information, transmission.

2.3 System Definition

The purpose of this section is not to define the word system, but to indicate how one links a question or thread analysis to what one considers to be the system for the particular case. In much of what follows in this paper we use "sensor system" as the example, broadly defined to be all components and actions from the point at which a target is detected to the point at which weapon/target pairing is accomplished. With this definition, one can list those functions performed by this system:

Sensor System Functions (Actions)

At Sensor Platform	At ISR Center
Receive Command	Receive Data
Move Platform	Fuse Data
Command Sensor	Interpret Data / Decide
Search	Assign Sensor
Detect	Create Target Folder
Transmit Data	Send Folder
	Mensurate
	Nominate Target, Transmit

The above assumes that there is some type of central function, ISR Center, or more than one, that receives sensor information and acts on it. However, the listed functions are independent of the exact structure of the sensor system. The functions are shown in the order that data is developed by the system, starting with the sensor on a platform being moved into position, through detection and transmitting information, processing the information at an ISR site, and sending the final target nomination out of the system.

Having defined the system, it is fairly easy to see the tags that would be attached to data for one of these functions. There would be significant number of meta-tags that identify the experiment, platform, and other context. Then there is the Sensor tag to identify the data as belonging to the sensor class, followed by other tags to designate specifics, such as it refers to transmission of a command to the sensor platform from the ISR desk.

A datum will have only one set of meta-tags, but it can have more than one set of system tags. For example, information probably will be associated with more than one system, such as the sensor system and the COP. Thus, tags appropriate to both will be present. This allows inter-system relationships to be examined. An example could be how a specific sensor control configuration contributes to an improved COP.

2.4 Level-3: Results and Analysis

Level-3 results address capabilities at the operational level. Thus the tags will be derived from major operational concepts, such as:

TCT	Time Critical Targets
STOM	Ship to Objective Maneuver
NCW	Network Centric Warfare
COP	Common Operating Picture
CAS	Close Air Support

These results will have been obtained from a single experimentation event or by synthesis of results from several events. In either case, the result in the database needs to have a tag that identifies the event(s). It is not only possible, but probable that information that applies to one concept can apply to one or more others. Thus the result will have tags for each of the concepts to which it applies.

Many of the results will have been developed from information in Level-2 or even from data in Level-1. It is important to identify the trail(s) through the data from which the result was developed. Tags are also used for this purpose. This allows one to access the supporting evidence for a result.

The best way to understand the relationships between analysis, the data system structure, and the use of tags is to consider an example analysis question. The following is a constructed, rudimentary example of the process, presented as a set of logical steps. It illustrates a thread.

<u>Analysis Question</u>:
How well can we do TCT? (Note poorly constructed, broad question)
Results Pull: Pull TCT tagged data from Level-3.
Results: A is good. B is not so good.
Concurrent FDP and TCT with the same platform is difficult.

These pulled results may be sufficient as-is or one may wish to use them as a starting point to explore more deeply. Then, one needs to ask a more in-depth, specific question and do another information pull, probably from Level-2 and even Level-1. Continuing with this example, assume the interest is in the concurrent FDP/TCT result.

Analysis Question:	What interaction between TCT and FDP reduces the ability to do TCT?
Information Pull:	Pull TCT and FDP tagged information from Level-2. Only pull information that has the same platform tag.
Information:	Difficulties with tube loading. Insufficient SAM rounds. TCT C2 configuration too slow for FDP

This information focuses one on one or several aspects of the problem. At this point a third (or more) analysis questions can be posed. In this way the thread of information is built up.

3rd Pulls:	Pull the connected C2, weapon system, sensor system: information from Level-2, and data from Level-1.

Other iterations in the process will occur until the analyst is satisfied with the information or there is nothing new to be found. A result of this analysis may be to create new results and information, and archive them with the appropriate tags.

The above example focuses on using the database for analysis, starting with results that are already in Level-3. In order to have results in Level-3, analyses may have already been done. It is also possible that the results were inserted directly from expert observations made during an experiment. This introduces the need for two types of tags for Level-3 results. If the result has been inserted, the tags will identify the concept and whatever context is needed. If the result comes from analysis, it is necessary to identify the thread, for which a tag is needed.

The above analysis example started with an analysis question, accessing a result that already existed, then drilling down into Levels 2 and 1. Because of the result accessed, the drilling down began with looking for instances of TCT and FTP on the same platform. The example ignored the fact that the result was already present, and that thread paths already existed, in order to illustrate the analysis process.

2.5 Level-2: System Information Tagging

Analysis begins with a question, then assembling the appropriate tags to pull the thread. Assuming that one wishes to generate new results, the pull will be from Levels-2 and 1. The following two sections describe the tagging schemes for these two levels.

Level-2 will contain much context meta-data. Examples are:

Event identifier
Operation or MESL within the event
Type of operation being examined
Description of the specific C3I structure
Descriptions of the specific hardware and software systems

With each datum in Level-2 there will be tags identifying the associated meta-data. Level-2 information deals with system capabilities. A example of defining a system was presented above using generic sensor as the example. It illustrates the many subsystems that make up the total system. Level-2 information can be for a system, subsystem, or combination of subsystems, as illustrated in the following diagram. Also illustrated is that archived information can be a subjective "opinion" or can be a "result" pulled from Level-1 data (Figure 2).

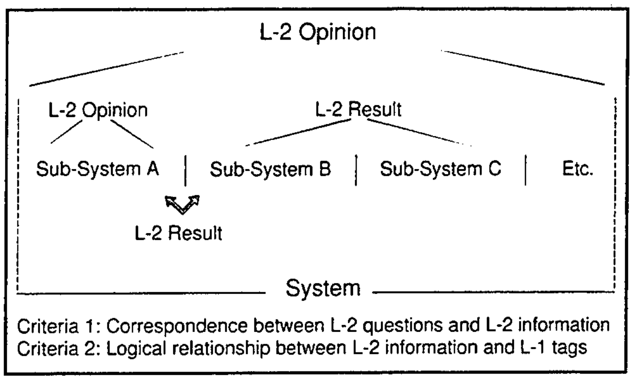

Figure 2. Level 2 opinions concerning the performance of a particular system as supported by L-1 data.

Recall that the data tagging structure has three categories: Things, Attributes, and Actions. For Level-2 information, actually for all data, the Things category tagging is natural. It consists of identifying the system itself and those things on which it sits. Attributes is also natural. The information can be a status report made at a particular time, what the mission is, the workflow, etc., and it can include more than one attribute in a single data entry. Actions at this level are more subtle as a category. At Level-2, Actions refers to information about system performance when an Action is being performed. Reporting on the status of a communication system might be that it is down. Reporting on its Action might be that the data rate is too slow for a particular peak load. Such information can be time marked, can refer to a time period, or may have no time associated with it being a general capability comment.

2.6 Level-1: Data Tagging

The distinctive characteristic of Level-1 data is that it contains events that occur at a specific time. Event data can be subjective or objective. Examples are:

> Objective: a target folder being sent to the fires cell, or a STOW simulation target inject
> Subjective: an observation or an opinion, such as an assessment node becoming overloaded

Subjective opinions are needed in Level-1. An example shows the importance of doing so. Take the case of an observation that an assessment node is overloaded. There may be available for that time period objective data that three sensor hits arrived at the node within a five minute period. Combining the subjective and objective data allows one to draw the conclusion that this node becomes overloaded if more than two targets are to be processed within a 10 min time period. This conclusion could be a Level-2 datum entry for the system.

There is little difference in the tagging for Levels-1 and –2. Event time is unique to Level-1, and Level-1 will always deal with an action, and be so tagged, while most information in Level-2 does not.

A better understanding of tagging at the two lower Levels of data/information can be obtained through examples. The sensor system is again the example. Thus, the "sensor system" tag is understood to be attached. We only list the specific tags for that data, not all the context tags, such as platform and sensor type.

	Data or Information	Partial Tags
Level-1 data:	Time to create folder	Decide, GISRS-M Terminal
	Time to mensurate	Decide, PTW+ Terminal, Target Type, Physical Environment
	Target info transmission	Information, Target-Information, Transmit, E-mail
	Time for weapon/target pairing	Decide, LAWS Terminal, Fires Cell configuration reference
Level-2 info:	"The fires cell configuration significantly reduces the TCT timeline when compared to a baseline configuration."	TCT, Latency, COP(?), Fires Cell configuration reference, person entering opinion or analysis thread reference

This conclusion could have been produced directly by an observer or by accessing the noted Level-1 data. If it came from the Level-1data, perhaps from that data referred to in this example, then a better Level-2 statement and tagging would be:

Level-2 info:	"The use of GISRS-M, PTW+, and LAWS in a JFE Cell configuration improved the TCT timeline."	TCT, Latency, JFE Cell, LAWS, GISRS-M, PTW+ analysis thread reference

The following is a constructed example of Level-2 information at the subsystem level.

Level-2 info:	"TARPS-CD imagery did not have sufficient resolution"	TARPS-CD, Detect, Target Type, TCT, Environment, Location

If the observer logged a time at which this observation was recorded, it could be possible to correlate it with Level-1 data concerning an actual target, sensor status, etc.

3.0 EQKMS Methodology

A key facet of the knowledge management process is the organization of information to enable various levels of searching and indexing. This includes the creation of metadata to summarize and categorize data. The knowledge repositories will contain output from various processing algorithms including qualitative, relational, neural, agent, and rule-based. Once in a uniform structure, the various search and retrieval methodologies can be applied against the repository to provide perspective within and across FBEs. Categorizations of qualitative resources specific to the needs of IJWA analysis, and implemented in the Ethnographic Qualitative Knowledge Management System (EQKMS), address information sources as variables in search scenarios: either high-level from decisions to specific events or vice-versa.

Present levels of analysis are addressing variables such as decision-making processes in Fires, discussions of data flows in critical systems, observations of command officers and pertinent post-FBE analysis, human-in-the-loop operations at various nodes, output from electronic workstations, etc. As the knowledge repository builds, with input from various FBEs, the system will support pattern recognition and matching across FBEs.

An objective of the IJWA EQKMS project is to support FBE analysis using classification schemas which enable high-level data extraction to support multi-level reporting, including the capability to drill-down from high-level decisions to supporting data, and to expand-up from event data to actions and results. Analysis in support of this process will provide a continual stage of synthesis into high level results which assess overall operational efficiency. This analysis is derived from data mining into the knowledge repository and the application of various knowledge management and artificial intelligence tools to extract information from the system. Perhaps the strongest rationale for this approach is that the results will contain the thread that generated the result. The original data and context will not be lost—which is a problem common to other methodologies. Thus, if needed, the thread can be easily traced to source data and the result, decision or analysis evaluated in the original context in which it occurred.

3.1 Data Capture Variables

Many types of data are required to successfully analyze FBEs. The major categorizations of qualitative and quantitative information, and the sources of the information, are identified within Figure 3.

The first two data types listed deal with specific events that occur at specific times. The next two deal with systems and processes, a step higher in abstraction and synthesis. The last two deal with the results of the various operations within the experiment. In order to advance analysis in these areas, within the context and with the capabilities as described above, a methodology for information organization was developed.

3.2 Systems Organization

Required attributes for the EQKMS include speed, access to a wide variety of qualitative and quantitative information sources, and extraction efficiency. Ideally, the methodology should

- ✓ Experiment Events
  - Observer data logs
  - Operator logs
  - Simulation injects
  - Electronic data
- ✓ Information throughput
  - Electronic data
- ✓ System and sub-system performance
  - Expert opinions
  - Post experiment interviews
  - Electronic data
- ✓ Process capabilities
  - Expert and operator opinions
  - Post experiment interviews
  - Electronic data
- ✓ Evaluation of experiment results
  - Operator opinions
    Analysis
- ✓ Experiment results implementations
  - Interviews with the Fleet

Figure 3. Primary qualitative and quantitative data categories.

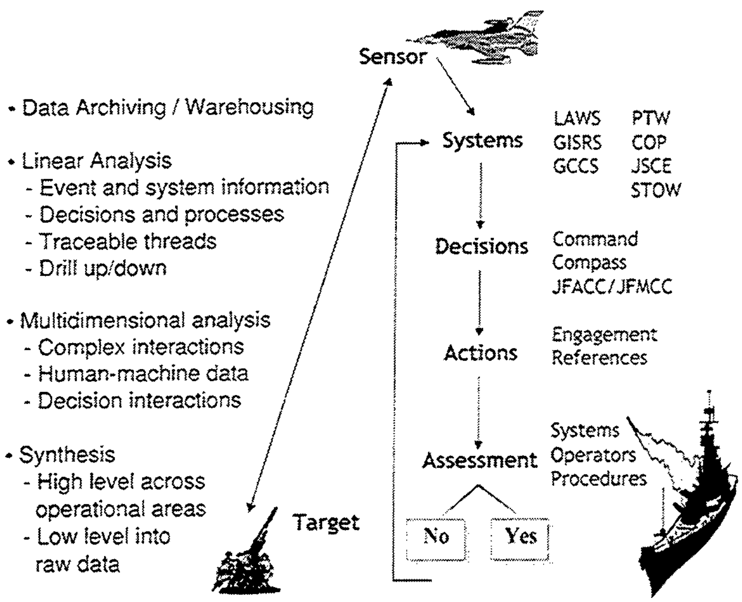

Figure 4. TCT qualitative analysis process.

support data and information extraction from source systems. In other words, the original processing, reporting, and other output capabilities of the source systems should be supported. For situations requiring contextual searching or mapping across loosely connected variables, the methodology should enable human knowledge managers to quickly scan, associate, and link pertinent events. FBE analysis would thereby be supported through:

(a) the archiving of information from many events so that synthesis can be easily done across events;
(b) the efficient extraction of information through an organization of information into topical areas, thereby speeding the analysis processes and providing an avenue for search and retrieval linkages across systems and resources;
(c) a methodology for efficient correlation of data across parameters, thereby enabling the development of knowledge bases and extraction processes which would be difficult for analysts to develop on their own.

An initial application of the above involved the creation of TCT timelines using target numbers to track events and decisions specific to targeting (Figures 4 & 5). IRC chat information was synchronized using target numbers and these numbers were searched across the chats. In the near future it will be possible to pull information from the observer data-logging sheets in the same manner. This addition will provide context to issues faced by operators in the FBEs. A typical search of a target number will reveal all operator activities regarding that target. With additional knowledge processing the target numbers can be linked back to the original sensor information. The linkage of the qualitative with the quantitative will produce specific events and associated actions. The inclusion of the observer data logs will provide an objective assessment to include events, operator actions, and any additional variables which may influence the processes.

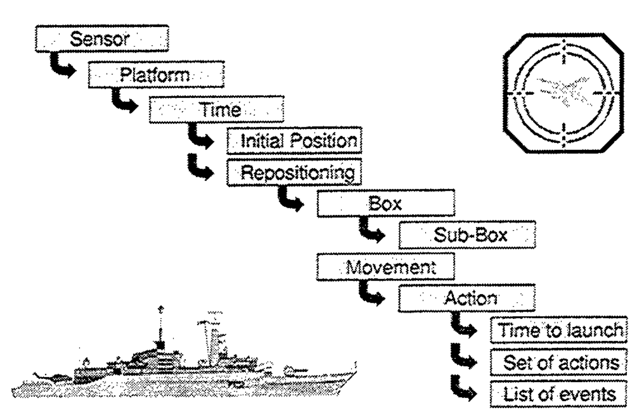

Figure 5. Example information flow for qualitative analysis.

Thus, the data structure organization methodology will allow one to construct data extraction threads that address specific operational and system questions. The data extraction methods may be specific to questions unique to a particular FBE, and in the future, across FBEs. In a projected application, given adequate data input and processing resource organization before an experiment, and given that proper data can be entered into the system quickly enough, the KM system could help in assembling the Final Report. A long term objective would be to provide analysis and assessment with increasing speed and efficiency. The tools and approaches being developed in the EQKMS will enable this evolution. An external variable not within the control of the EQKMS is the data organization structure imposed by systems throughout the FBE. To the extent that standardized data and information organization structures can adopted by all systems and users then the information can be ever more quickly synthesized and integrated into the analysis process—and perhaps one day into decision processes. The EQKMS is utilizing a methodology to support such data and information organization.

4.0 Knowledge Hierarchies

Qualitative information is being organized, tagged and labeled following methodologies developed on two levels. The first level addresses the coding, tagging, and detailed organization. The second addresses the means through which various systems can organize their information and data to assist in detailed extraction across computer-based systems.

4.1 Decision and Event Extraction

Data archiving to support decision and event extraction consists of tagging and coding based on a methodology which can be applied across information resources. This information is categorized on the 3 levels discussed earlier. Level 1 organization considers objective and subjective data that directly address events. As discussed earlier, Figure 1 illustrates the relationship of "things" to "attributes" and "actions" in the EQKMS schema. This simple categorization enables the data coders to seek existing relationships in the data and uncover mixtures of variables which provide insight on the issues being investigated. A ready example is the categorizations of the "process" issues in IRC wherein one of the data coders spotted problems that operators were having with communications—both human-to-human and human-to-machine—and began inputting process classifications into EQKMS.

A second level of analysis follows the illustration in Figure 2. Level 2 analysis concerns the performance of a particular system and interfaces with Level 1 analysis to discover relationships between the application of a particular technology and objective feedback on the processes invoked during the application—whether human or technological. This analysis is reflected in the "process" issues in EQKMS. When the live operator Level 2 discussions are coupled with the corresponding assessment by the observers in the data sheets there is a strong basis for objective assessment of a particular system or operation.

Level 3 analysis builds on the Levels 1 and 2 to present conclusions that address system capabilities at the initiative level. At this level various decision methodologies can be applied against the Level 1 and 2 data to arrive at high-level analysis. Analysis and representation categorizations include the following:

- Robust decision analysis and support information utilizing structures supporting linear, multivariate, multidimensional analysis
- Multiple user relevance, supporting non-projected and unanticipated environments and circumstances
- Schemas which represent useful knowledge categorization and provide frameworks which stimulate questions and insights
- Knowledge bases to better understand systems and processes, and to identify usage and implementation patterns and problems
- Conclusions addressing capabilities in: Time Critical Strikes and Fires; Theatre Ballistic Missile Defense; Common Operating Picture; etc.

Within EQKMS the analysis above is supported through data mining into the knowledge base to produce relevant tags and process information linked to the source data. Plus, the search produces a thread back to the original information and data for in-depth analysis. An added value is that the qualitative search technique produces the result within the original context.

4.2 Cross-System Organization

Linear and multidimensional analysis, within the context of the EQKMS distributed qualitative knowledge system, would typically begin with a specific event or decision. For example, the identification of a target, process or system. As a first step the variable would be traced from inception to conclusion. Event, decision and time variables would be tracked in a linear fashion. Qualitative multidimensional analysis extends the scope of the inquiry to bridge parallel, adjacent and complementary information resources. For example, an event or decision can be tracked from inception to conclusion through linear analysis, and through multidimensional analysis this information can be supplemented with additional perspectives and supporting data—such as observer logs, independent assessments, post-FBE analysis, data from other systems, etc. Time, event and decision data provide the common link between the various resources. The end result supports high-level and low-level analysis across time, and linear and multidimensional assessments of event and decision variables.

In addition, the above variables may be cross-referenced to the human analysis taking place within IJWA to further assist in the assessment of information flows, decision processes, and systems issues. For example, sensor data may be linked to an event—and both linked to human actions at each step in the decision process—with the collective linked to various levels of analysis (both real-time and post-FBE). In the post-FBE analysis, the IJWA coding and tagging process itself produces a level of analysis as the trained knowledge workers spot abnormalities and deviations in FBE systems and processes. Such high-level analysis is not available without human processing of the information. Unexpected results can be identified and tagged as intervening or unforeseen variables. An example would be a systems process, a human communication error, or an assessment of delays or time differentials.

The key to synchronizing these various systems and levels of analysis resides in the knowledge hierarchies—which are common across information sites, and as feasible, across data-generating units. A common information organization structure (Figure 6) will enable diverse systems and

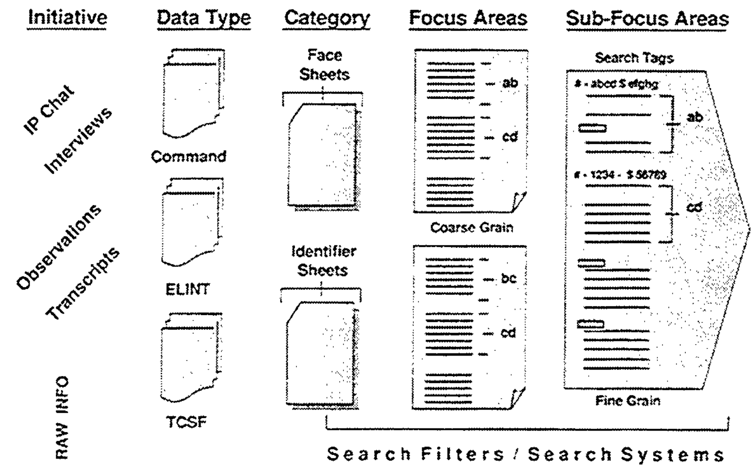

Figure 6. EQKMS data and information organization process.

distributed operations to make their information available in a format that lends itself to analysis across FBE operations. The long-range implications of a uniform information classification hierarchy are considerable and at the basis of the EQKMS methodology. Specifically, the system is being designed to support various levels of analysis within an open, distributed, [and as feasible] object-oriented infrastructure.

This methodology can be contrasted with a singular or proprietary approach wherein all data must be processed within a single methodology or architecture—which is generally costly and time-consuming. Rather, the EQKMS methodology accepts data from whatever source and location and organizes the information for access and data mining via various techniques and approaches. It does not require that all information be loaded into a central service but instead utilizes data and information in its native format and, as feasible, applies various search, retrieval and processing methodologies to the data. This methodology thereby utilizes existing processes and personnel and does not require an extensive recoding or reformatting of data, only the processing of the source data. This processing may include the tagging of pertinent information (Figure 7), the generation of metadata or meta-indexes, full text and object or relational searches, and knowledge or database loading of either the core material or the metadata derived from that material. Metadata indexes will enable a fast and robust search and retrieval of both processed and unprocessed information (via searches) for output to reports, web-based display, or transfer.

Weapon Expenditures
- Type
- Number
- Firing Unit
- Target

Target Size Control
- Rounds
- ERGM
- LASM

Time Periods
- C2 Command Decision Time
- NLT
- Reserve Time
- Time of Flight
- Max Launch Time

Time Events
- Acquisition
- Nomination
- Yellow
- Green
- Authorized to Fire
- Weapon Fired
- Negated
- C2 Actions
- Launch Time
- Time on Target
- Estimate of Dwell
- Mensuration Complete
- Mensurated Coordinates

Target ID
- Sensor Event (Radar, UAV, TEL)
- Target # - Track #
- Position of Target
- Area Designators - Block
- Latitude and Longitude

Figure 7. Low-level data tagging variables applied to files.

4.3 Ethnographic Processes

The Ethnographic Qualitative Knowledge Management System (EQKMS) facilitates the analysis of qualitative data collected for both qualitative and quantitative research. The process includes formatting the data, coding data as a means of noticing interesting information, tagging relevant documents or phrases, and entering code words to assist in the filtering and extraction of knowledge. As an example, in FBE Golf, EQKMS processing of the IP Chat files proved to be an efficient means for contextual analysis of both operator-specific and environmental variables. The qualitative data was primarily textual and included materials such as interview transcripts, field notes, open-ended survey responses, chat files, and various reference documents. The knowledge processing cycle within EQKMS is itself a form of high-level analysis, with the knowledge workers noticing interesting relationships within the data, marking pertinent phrases with code words, and integrating variables across resources during the search processes. Within EQKMS, the IJWA analytic scheme for noticing relationships in the data can be as simple or as complex as is required. IJWA can also revise and refine these schemes as the work progresses.

EQKMS is thereby a collection of procedures designed to enhance the process of qualitative data analysis. Although there are varying perspectives on how researchers should conduct such activities, the essence of qualitative data analysis almost always involves the process of noticing, collecting, and thinking about things that are interesting within the data. With the FBE Golf information this process has allowed IJWA to put not only a large amount of data into the knowledge base but also information from various perspectives—1st, 2nd and 3rd party. Once imported into the EQKMS, data files are in a 40 character line, hanging indent format. This makes the files easier to read, code and organize compared to non-qualitative systems.

The process of code mapping consists of reading, rereading and noticing interesting events in the data and then marking those things for later retrieval. Code mapping is a means of sketching out the analytical scheme of the data, as well as a step that allows the searching and filtration of information by these code words. EQKMS Phase 1 employs a code book as a type of meta-index. It references the code words attached to the data file. As code words are added to the files they are automatically added to the code book. The code book contains information about each code word, and thereby about each item in each of the files—including the parent code associated with the code word (if there is one); the nature of the information being coded (e.g., whether or not the code word defines text); definitions associated with the code words; the date the code word was entered into the code book; and the last date the code book was modified. The code book also allows for the organization of the codes into hierarchical groups called families (similar to trees in object-oriented systems), and the ability to view the code book as a list or a family tree depicting the relationships among parent and child codes.

While the analyst is working with and thinking about the data they can use the EQKMS Memo function to record ideas, hunches and thoughts about the data from almost anywhere in the system. There are three types of memos: project memos, file memos, and text memos. Each memo can be up to 32 pages in length. Project memos are memos about an entire project (e.g., IP Chat or FBE Golf). A project may have up to 1000 memos attached to it. File memos are memos about an entire file. Each file in a project can have up to 1000 memos attached to it. Text memos refer to specific sets of lines within a data file, and each line may have up to 26 memos. In addition to the three standard memo types, EQKMS Phase 1 allows the analyst to create an unlimited number of memo types.

The knowledge workers coding the FBE GOLF IRC files noted that it was beneficial to use the EQKMS speaker/identifier code features. This provides the coder with the ability to identify the current speaker/source within the file. Because identifiers can be used to represent more than just speakers, this code is frequently referred to simply as an "identifier". Identifiers are defacto code words which can be searched and filtered. This feature can be used when querying or data mining into the EQKMS. For example, if the analyst would like to see all data segments entered by a particular chat participant in relation to a specific target this could be filtered out of the EQKMS by searching on the participant's name or call sign and the target number. Within the EQKMS Face Sheets and Identifier Sheets are lists of variables that act as filters during searches. Both Face Sheets and Identifier Sheets are based on templates that are created by the EQKMS analyst.

The template is a list of up to 40 variables (e.g., target_num, munitions, sensor) that are the basis of Face and Identifier sheets. A Face Sheet is thereby a set of information about a whole data file. It lets the analyst restrict a search to data files that meet conditions specified on the Face Sheet. An identifier sheet is a set of information about a speaker or a section within a data file. It enables the analysis to limit a search to segments containing identifiers that meet conditions specified on the Identifier Sheet. For example, in a chat file with multiple participants, Identifier Sheets could be used to record the rank, name and location of each speaker.

Search Filters are a means to restrict searches to segments that meet specified conditions. A search can be filtered using 1) Face Sheets, 2) Identifier Sheets, 3) Identifiers, or 4) File Codes. Combinations of filter types are supported. The search procedure itself offers several options for analyzing data, including single code searches, multiple code searches and identifier searches. A single code search scans the data for text segments identified by a code word. A multiple code search locates text segments identified by two or more code words linked by AND and NOT. For example, a search can be conducted for all segments identified by CODEa AND CODEb but NOT CODEc. An Identifier search looks for text associated with Speaker/Section Identifiers in the data file. The text associated with an identifier includes all the text from the identifier down to the next identifier in the data file.

The EQKMS also has several quantitative outputs associated with a qualitative search, including number of search segments located, frequency of each occurrence, and summary data based on the occurrence of associated items such as memos. A segment output will display the text defined by a code word and associated cross-referenced information. Frequency output displays the numerical counts of coded segments and calculates relative frequency percentages for code words—both within and across data files. A summary output lists the line number coordinates of segments and information such as the size of a segment (lines or pertinent information). When memo output is selected the EQKMS displays the memo attached by the knowledge worker or analysis to a particular file or group of files.

4.4 Ethnographic Application of Methodology

The IJWA assessment of FBE-Golf data included the integration of IP Chat into EQKMS. Files were categorized and coded based on knowledge hierarchies (functional decompositions) representing various operational levels and decision-making processes. These ranged from command to operational decisions, and from system-based actions to individual interpretation. The subject area involved targeting processes: from initial sensor readings, to target number assignment, to the addressing and resolution of the target. The EQKMS process captured the qualitative data in the targeting process—in this instance, the discussion, opinions, systems data/references and commands.

Chat files are the means through which the participants in the experiment coordinate dynamic elements in the FBE. The different chat files address different aspects of the operations. The focus of the EQKMS analysis is to structure the topics under discussion to provide high-level analysis of the dynamics of the activities and interactions. For example, chat regarding the actual engagement and resolution of targets is mostly found in the ENGAGEMENT area, and sensor events are more commonly discussed in the GISRC, SENSOR PLANNING, and TARGETS-SENSORS chats. The EQKMS analysis process utilizes the knowledge management hierarchies to categorize, filter and search this data. Organizational hierarchies implemented through the chats address platforms, operators on these platforms, and command level decisions. Also addressed are chat topics discussing the overall cohesion of the FBE and the common operational picture.

Worthy of note is that often data that appears as though it should be limited to a specific chat will be found in files where it is not expected. For example, Battle Damage Assessment (BDA) would be expected to be found in the BDA chats but is most commonly discussed in the ENGAGEMENT chats. Many command issues that would be expected to be in the COMMAND chat are in the ENGAGEMENT or JECG_CMD chat files. The EQKMS allows not only the organization but the filtration of information across chats, and thereby across participants. Assessments, filtrations, and drill-down capabilities can thereby work across, or integrate, data sources, participants, events, etc. A benefit of the EQKMS methodology in this process is the ability to extract relevant data pertaining to command and operational decisions and then "drill down" into supporting insights. Through the searches, and the corresponding assessment of the grouped and categorized results, it is possible to not only assess the circumstances, and intervening variables, but the personal insights and perspectives of the participants.

5.0 Knowledge Organization Hierarchies

The application of the knowledge processing hierarchy outlined in Figure 6 is applied to a COMMAND functional decomposition sequence in Figure 8. In this application the initiative is IRC and the specific chat area is identified as the data type. The next layer is the category, in this instance discussion of C2 issues. Focus and subfocus areas delineate means to organize data and information of increasing specificity. There are several rationales for this approach. Foremost is standardization across diverse data and information sources. Without a common frame of reference those developing infor-

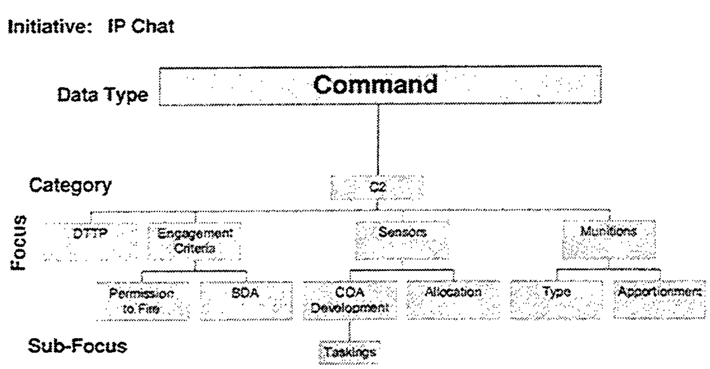

Figure 8. Application of the information organization process schema to a data resource.

mation and knowledge systems will have a difficult time integrating information—and understanding what information another unit may be processing. Ideally, the various information and knowledge systems might exchange information and one system might utilize the output of another. In such an application a common hierarchy of information or categorization would allow an easy reference and exchange. As resources are linked across the networks these hierarchies may allow information resources at diverse locations to be interconnected and operate as a cohesive unit.

For example, sensor data is presently processed through a number of operations, all using proprietary information storage and report generation systems. When one system wishes to exchange information with another the data or information must be processed into the new system. This is often a "top down" process. Using Figure 8 as an example, if all operations utilize "Command/ C2/Sensor/Allocation" as an information organization schema then the process of linking various resources becomes more probable, the overall cost of information processing is reduced, the speed of information transfer is increased, and the likelihood of knowledge searches producing comprehensive analysis is increased.

An application within IJWA is a case in point. EQKMS is an application of the coding structure discussed earlier and illustrated in Figure 6 to categorize FBE qualitative and quantitative data. Continuing the Figure 8 Command area as an illustration, the information can be organized, tagged and coded using the hierarchy as a reference. Various identification sheets can be coded. The categorizations enable an increasingly finer tuning of the searches. A fine grained search, specific to the subfocus area of interest, would produce linear knowledge that is narrowly tuned to the event, decision or process of interest. An example would be a search on a target number or a process (Figure 9). The target is addressed by different operators in different chat areas, with each operator addressing different aspects of the target. In this example the discourse is charted by time and operator. The figure shows some of the search tags entered into the data files—which open avenues for an examination of broader issues affecting an operation. A coarse-grained search would reveal the item of interest and related information as documented in the sample, plus, related information. For example, a coarse grained search may draw sections of post-FBE interviews, observer insights from the data sheets, or reference information used to make a decision or enact a process during an FBE. All of these may be tied to a specific target or process issue.

```
SEARCH RESULTS          7/20/2000 8:28:40 PM
SEARCH CODE: T#GA1700
SEARCH TAGS:
#-TARGET #-TARGET_NUM #-DTF #-GISRC
#-T#GA1700 #-T#GA1710 #-T#GA1720
----------------------------------------
FILE: #TC0405
[14:23] <Greg_IKE_GISRC> Anz - confirm
        jtw menstration of those target.
        what target nums?
[14:23] <ANZ_GISRC_9> ga1700, ga1710,
        ga1720...
----------------------------------------
FILE: #EN0405
[14:40] <DTF_IKE> anz_laws, pls ask
        anz-gisrc9 if they have established
        DTF for ga1700, ga1710, ga1720
----------------------------------------
FILE: #TC0405
[14:41] <DTF_IKE> anz-gisrc9, have you
        established DTF for ga1700, ga1710,
        ga1720.  I prefer to chat in
        target-sensors room.
----------------------------------------
FILE: #EN0405
[14:46] <ANZ_LAWS> What tgt number ? we
        fired on GA 1700,1710
```

Figure 9. Partial IRC discourse among TCT and Engagement operators addressing target, organized by time, with thread to original source file.

The COMMAND files in IP Chat contain mostly Command participants and some

GISRC operators. The focus of this category is to look specifically at battle command and to define the command decision-making process from the commander's intent, to COA development, to execution. This category defines the data on how the commander makes time-critical decisions based on BDA, realtime sensor feeds, and change to enemy COA. These categories are based on the trends developed from FBE-G. COMMAND is the primary place for members of the experiment to contact the Battle Watch Command (BWC).

Common issues discussed in the COMMAND data are: the allocation of sensors, specifically UAV sensors; specific targets; digital target folders; and target mensuration. Participants include the C6 Forward Battle Watch Officer (C6FBWO), the Joint Force Maritime Commander (JFMCC), and the COPCI. The COMMAND files are short in comparison to the ENGAGEMENT chat files which also hold much of the same type of data. The ENGAGEMENT chats have many more participants involved than the COMMAND chats because of the number of participating operators. In sum, from the COMMAND data it is possible to extract command level decisions regarding specific processes from sensor events and targets. The ability to filter this kind of information within the EQKMS hierarchy will help to show the effect on the experiment that the command level decisions have on the outcome (target resolution).

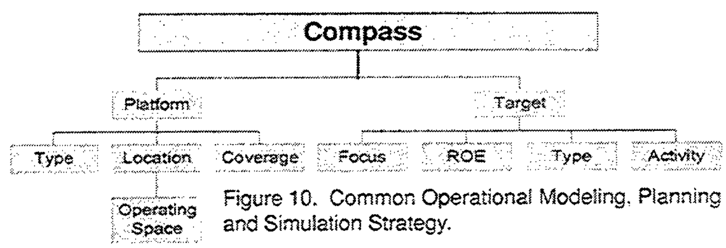

Figure 10. Common Operational Modeling, Planning and Simulation Strategy.

COMPASS looks at data from a single system to see how it relates to the decision-making process. The relevant data in COMPASS (Common Operational Modeling, Planning and Simulation Strategy) is in relation to: Rules Of Engagement (ROE); Platform location, coverage and type (usually ABL); operating space; and the troubleshooting of the COMPASS server (Figure 10). Future EQKMS activities in this area will link COMPASS platform and target information to operational data.

The COPCI hierarchy decomposes data from the common operating picture system (Figure 11). This data can be used to look at situational awareness and how it affects decision-making. This category is based on data from FBE-G. COPCI information categorizations address the FBE situation; threat/target activity, location, type and resolution; target verification; system status and procedures for system information entry; Restricted Fire Areas (RFAs); and Digital Target

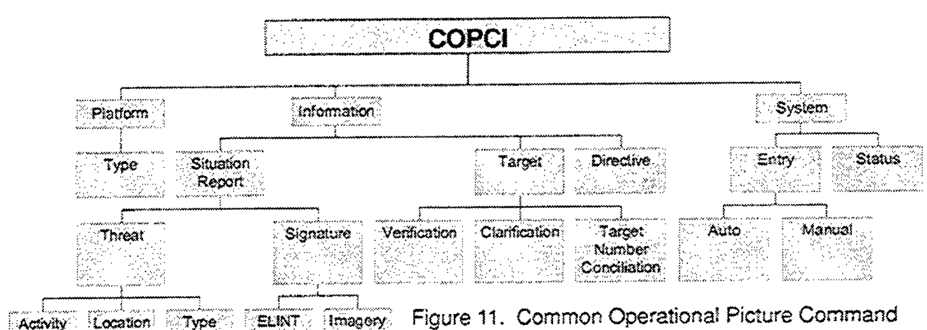

Figure 11. Common Operational Picture Command Intelligence.

Folder (DTF) establishment and maintenance. These topics are accessible through filtration and search procedures within EQKMS—which enables the desired "drill down" capability that is needed to access information from various data sources within the IP Chat files.

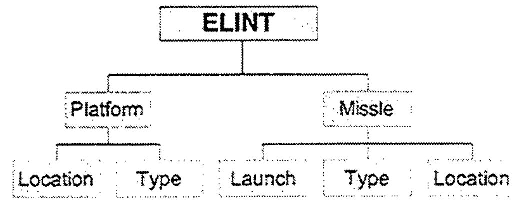

Figure 12. Electronic Intelligence.

The ELINT category (Figure 12) is structured to organize data specifically related to ELINT signatures. This category will be used to look at data during deliberate planning and time critical targeting. This data can be related to the target-sensors category.

5.1 Engagement

This category looks at how we can define data during the engagement phase of "sensor-weapon pairing." This category is closely related to sensor management or the target-sensor category. This data becomes important when comparing engagement qualitative data with quantitative data, such as from LAWS. ENGAGEMENT also addresses the integration of joint fires with the time critical targeting cycle. These categories are derived from trends seen in FBE-G and FBE-H.

The IRC ENGAGEMENT files (Figure 13) serve as a meeting and discussion place for operators at the workstations aboard various platforms in the fleet battle experiment. The battle environment that the operators deal with is very dynamic and requires that the members of the engagement chat be able to converse in realtime about the information they are receiving from various sources. These sources include UAVs, sensors, other platforms and other systems. It is a unique environment in that the operators have to be able to think and respond quickly to an ever changing operational picture of the battle field.

ENGAGEMENT is somewhat different from the other organizational hierarchies because there is an element of command structure. There were active command participants in the ENGAGEMENT IP chat—usually a LCDR and/or JFMCC, JECG DIR or JFACC. The prevalence of this command structure in ENGAGEMENT impacts the knowledge management structure of both the IP Chat and the overall knowledge management system. Specifically, in the design of the

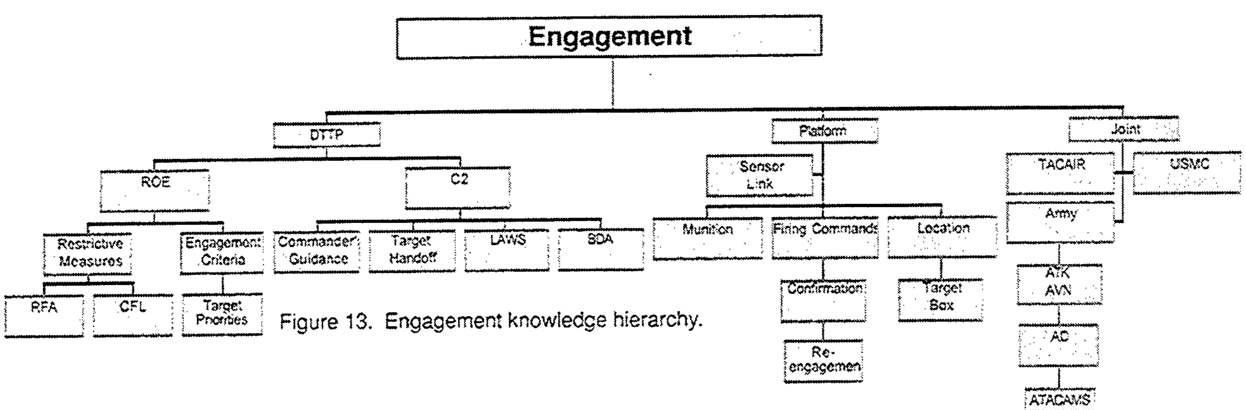

Figure 13. Engagement knowledge hierarchy.

EQKMS, references to senior level decision-making can be organized as distinct entities in the overall hierarchy of the knowledge management processes and actions can be filtered or searched based on specific command guidance or oversight information. This can provide a "drill down" from oversight or command perspectives into the actual target decision and resolution.

Other chat members active in ENGAGEMENT include LAWS operators, GISRC operators, and other members of the experiment who are involved in the actual engagement of targets. The discussion is based on the process of eliminating a target and includes steps from the injection of a target into LAWS (the most prevalent system discussed in the ENGAGEMENT files) from GISR or GCCS to the actual launch of munitions against the target. Other topics include: target information; mensuration of the targets; creation/management of digital target folders; management of the information between the various systems; engagement of the targets; prioritization of the targets; problems with target information; different types of munitions sent to targets; information about munitions in flight; new Time Critical Targets that need to be mensurated and launched on; and battle damage assessments.

In sum, in the knowledge management organizational structure, the Ethnographic Qualitative Knowledge Management System provides detailed references to each of the active elements in the ENGAGEMENT chat. In the knowledge design, the engagement focus is thereby on specific targets, and events addressing those targets, and pertinent command or specific decision processes of operators or participants. In the knowledge hierarchies (functional decompositions), the ENGAGEMENT data follows the sensor and identification processes and precedes the damage assessment. ENGAGEMENT is thereby addressed within the EQKMS as the component addressing target resolution and the command and decision structures forming the foundation for action.

5.2 FBECOP

FBECOP is for the categorization of data from the common operating picture system (Figure 14). This data can be used to look at situational awareness and how it affects decision-making. In application, the FBE Common Operational Picture chat area hosts GCCS-M operators and the technicians used to coordinate their efforts. This chat is crucial for keeping the COP up to date for GCCS operators and users throughout the experiment. The resources contain discussions of systems status and troubleshooting of these systems. For example, in FBE-Golf there were TASID and SIPRNET problems noted in the FBECOP chat areas. ADVISRT problems

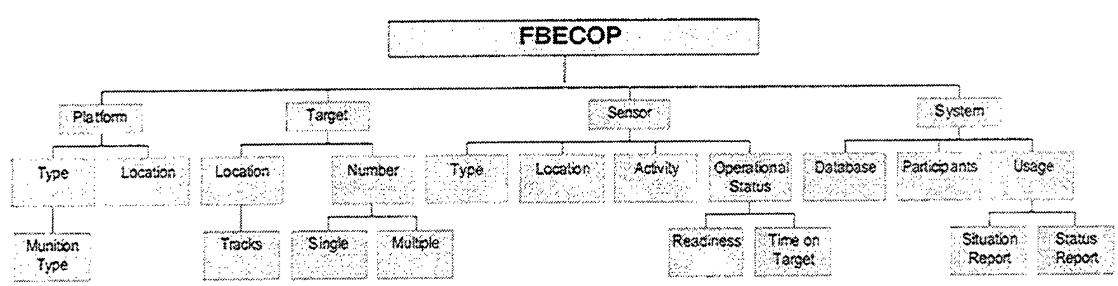

Figure 14. FBE Common Operational Picture.

were a topic of discussion, as was the process of downloading and installing software updates.

Within the FBECOP knowledge hierarchy there is significant structure for the recording of track status within the systems. The resolution of differences in system status in order to achieve a synchronized operational picture between various platforms in an experiment is a prominent theme throughout the FBECOP hierarchy. This would include discussion regarding specific targets, with a recording of type, activity, location, resolution, and munitions. The No Strike Zone and Restricted Fire Area overlays are discussed in the FBE data as well. Electronic Intelligence (ELINT), target information and UAV sensor information are thereby prominent information sources throughout the FBECOP knowledge hierarchy. In IRC, the FBECOP files contain information concerning targets in early stages of target nomination.

5.3 GISRC

This category is an attempt to look at a specific system (GISR) and to derive some common systems analysis from the qualitative data. The initial categorizations were derived from FBE-G IRC Chat. Systems status is the main focus of the GISRC (Global Information Surveillance Reconnaissance Capability) data, with sensor locations and missions as subfocus areas. The files contain some tactical data, but consist primarily of GISRC technical issues (Figure 15). In an FBE, the main purpose of the GISRC chat is for the coordination and resolution of technical issues confronted during GISRC utilization and GISRC data implementation. LAWS and GCCS systems also surface as a topic and are thereby referenced through the EQKMS knowledge hierarchy. Specific problems that are prevalent in the data address systems software upgrading and troubleshooting, TASID and ADVSRT problems, and communication difficulties.

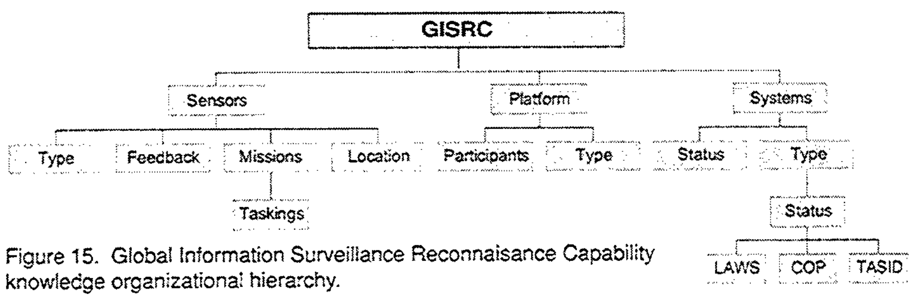

Figure 15. Global Information Surveillance Reconnaisance Capability knowledge organizational hierarchy.

The coding scheme used in the GISRC chat data allows IJWA to do searches that will output the segments of data that show the processes of troubleshooting and the areas that were focused on during FBE operations. For example, when target specific problems are discussed within the GISRC chat, this information can be referenced through cross-file searches on target numbers, and this information will be filtered and made available along with the rest of the data concerning that target. This allows IJWA to follow all information concerning specific targets and the technologies addressing the targets, and in GISRC, to focus on systems problems that may delay the total resolution time of the target.

Also worthy of note is that there are times when the GISRC chat is being used by UAVSIM operators for sensor allocation purposes. The UAVSIM participants, in some cases, were asked to disconnect and move their conversations to the TARGETS-SENSORS chat. This type of cross-system analysis is a strength of the IJWA EQKMS methodology.

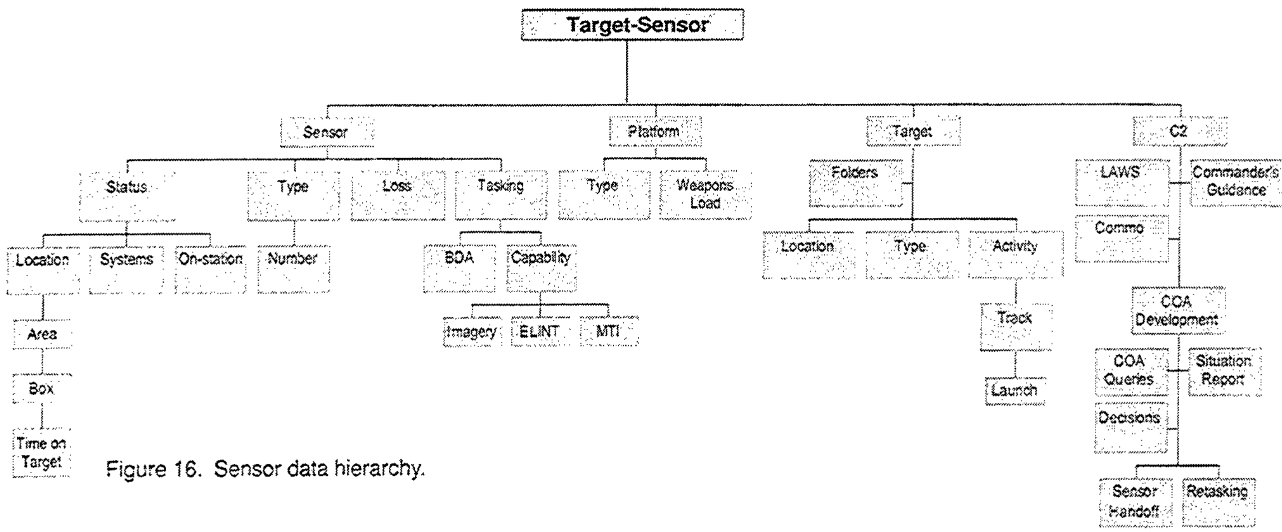

Figure 16. Sensor data hierarchy.

5.4 Sensors

The focus of this category is data related to sensor management (Figure 16). Looking at the FBE-G and FBE-H initial results, categories were developed that would define the relationship between sensors, commander's guidance/intent, and weapon systems. Eventually this data will be used to look at the relationships between deliberate ISR planning, and use of sensors during time critical targeting. Data concerning decisions on battlespace coverage and COA branches and sequels will be covered.

In application, the TARGET-SENSOR resource contains information utilized by operators in charge of sensor allocation and target sensor data. Target information is available as it pertains to sensor readings and the linkage between sensor reports, systems reports, and target nomination. Supporting information is also available, such as DTF data processing and target type references, location and activity.

Sensor status, tasking and sensor BDA are documented. There is a command element available in this resource and commander's guidance and command level course of action decisions are searchable in the EQKMS TARGETS-SENSORS data.

The most common sensor events logged in TARGETS-SENSORS is UAV data. There is a significant number of data segments that involve discussions about targets as registered by UAV sensors. The resultant mensuration of these targets, via the sensors, is available in the knowledge base. Much of the TARGETS-SENSORS data is "pre-target number" information, meaning that the data specifies the type of target and the location rather than the target number. EQKMS operators, by searching and linking the target numbers to the LAWS data and referencing TARGETS-SENSORS data, can link the target from initial reading to conclusion. The coding scheme for these files facilitates the searching of sensor events in relation to specific types of targets, target locations, enemy missile launch events, and specific target numbers.

The JECG_CMD knowledge resources also hold sensor data, especially data referencing P-3

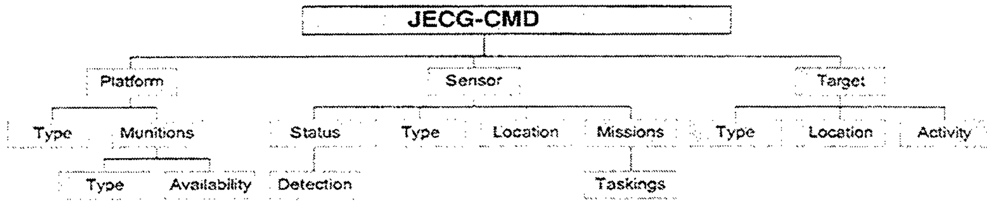

Figure 17. Joint Experiment Control Group Command data hierarchy.

sensors (Figure 17). The location, allocation, and events surrounding utilization of the P-3 sensors makes up the bulk of the data in the JECG_CMD IRC files. There are also some target specific discussions which concern target type, location and activity, but they do not generally reference the actual target numbers. JECG_CMD resources will be critical in correlating sensor events (sans target numbers) to the actual target resolution process. The IJWA analysts will be able to synchronize discussions in JECG_CMD and TARGETS-SENSORS with LAWS data and ENGAGEMENT files to recreate target events—from initial reading to identification and resolution.

5.5 Time Critical Strikes and Fires

This category focuses solely on the process of time critical fires (Figure 18). While related to the Engagement and Target Sensor categories; this is an attempt to even further isolate the fires process with a complete focus on time critical fires from deliberate planned fires.

The majority of the data held in the TCSF files concerns systems status in relation to the targeting stations. Some of the data is target-specific. The purpose of TCSF IRC is to provide a place for guidance requests and CONOPS (concept of operations) questions. The TCSF chat area also provides a place and means to facilitate the operational cohesion of the FBE.

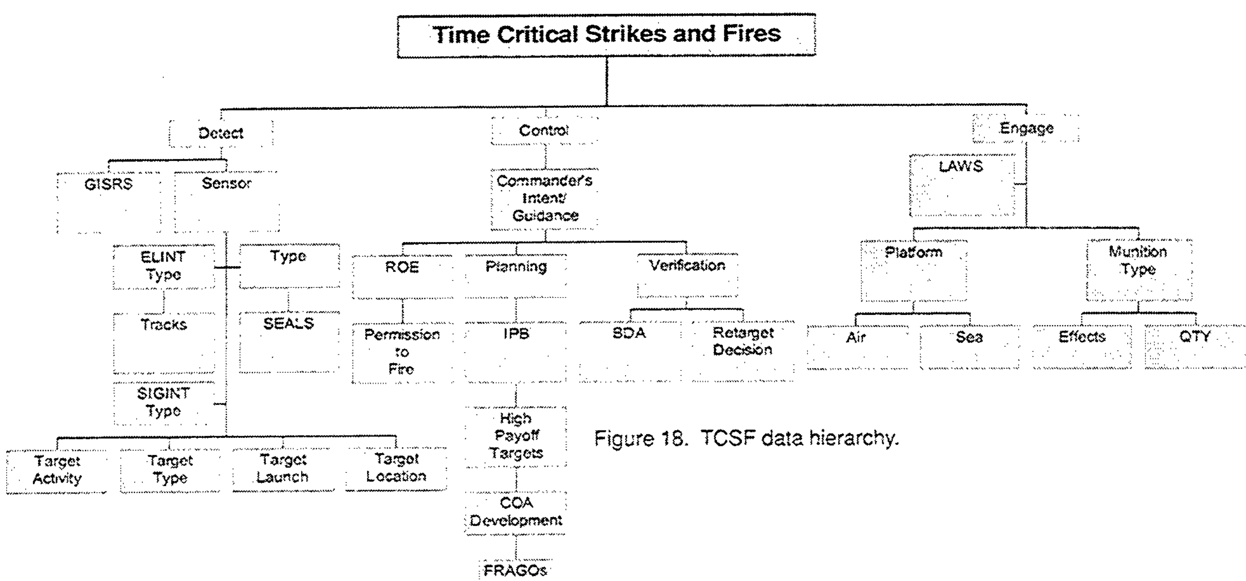

Figure 18. TCSF data hierarchy.

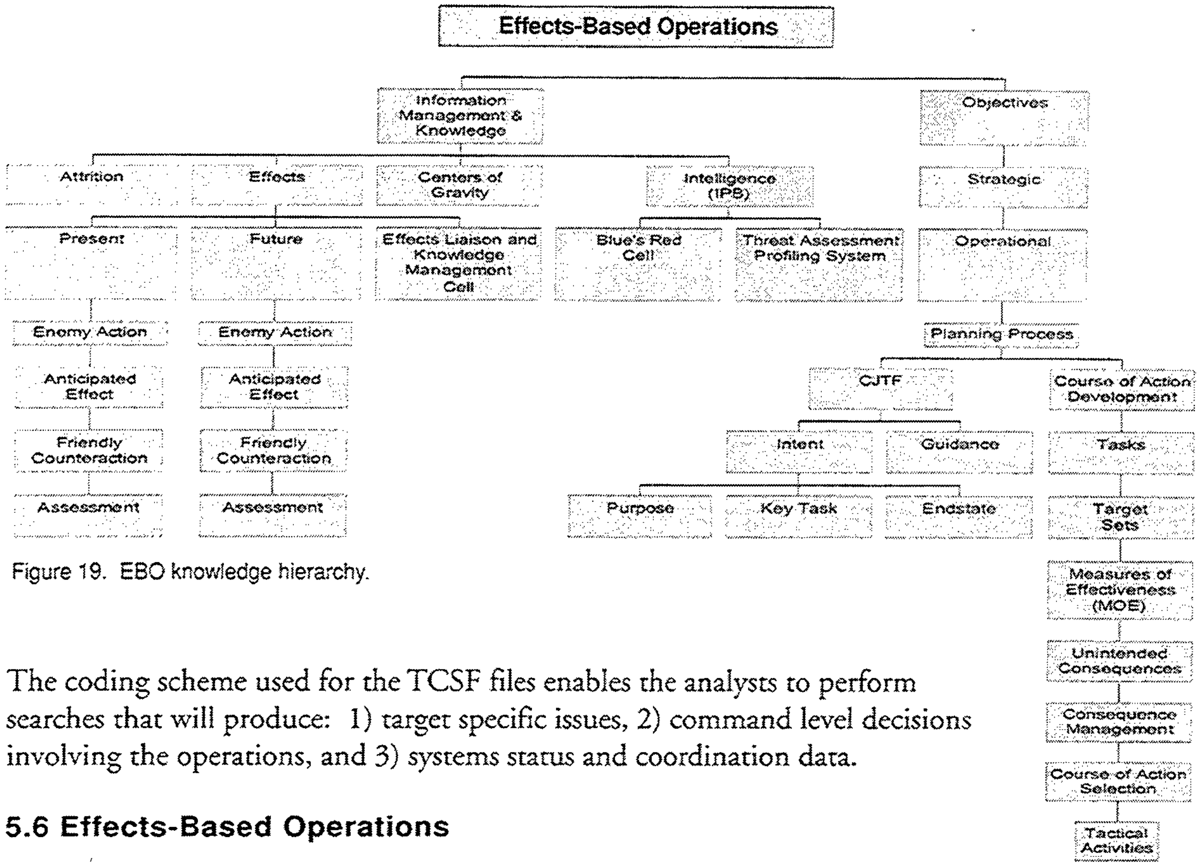

Figure 19. EBO knowledge hierarchy.

The coding scheme used for the TCSF files enables the analysts to perform searches that will produce: 1) target specific issues, 2) command level decisions involving the operations, and 3) systems status and coordination data.

5.6 Effects-Based Operations

EBO is an important process for deliberate planning. This category is based on EBO play during the FBE. Additionally, the subcategories come from EBO conferences preparing for Global 2000.

The EBO hierarchy is thereby a higher-order classification schema which addresses overall information and intelligence processes (Figure 19). This categorization contains macro-level analysis examining specific and relational aspects of the FBE. Foci such as blue and red cell activity can be charted against strategy and implementation to provide a perspective on a certain course of action and the results of that action given specific environments or variables.

5.7 Analysis Processes

Analysis is conducted during an FBE, immediately after an FBE, and during the traditional post-FBE assessment phases. Given the variety of systems and processes in an FBE the analysis will advance various perspectives, depending on the need, system or sponsor. The knowledge resources supporting this analysis must therefore be flexible and customizable if they are to meet the specific needs of the different analysts. In addition, the process of sorting, categorizing, and coding or tagging information also provides a level of analysis as the knowledge workers identify trends, deviations, or areas of interest in the data. Discussions about targeting and communication difficulties, mensuration processes and problems, missile guidance issues, and IVOX and VAT communications issues would be an example.

There are also resources unique to analysis—generally labeled as containing analysis information. In some instances, such as in the FBE-Golf chat files, this data is redundant with information found elsewhere but is synthesized into analysis files as a means to record significant events. This channel may be optimally used as a forum to assess current situations within the experiment and thereby provide an advanced level of analysis. This would be useful for data organization, filtering and searching. A benefit of EQKMS in this process is the ability to extract relevant data pertaining to specific areas of analysis within an experiment, including ANALYSIS chats as well as all other files contained in IP Chat and developed throughout the experiments. This allows the organization and filtration of information even when the desired data does not reside in the files in which it is expected to be logically associated.

For example, after coding and analysis of the ENGAGEMENT files and the FBECOP files it was apparent that there are difficulties in target mensuration for LAWS operators. Once a sensor detects a target, and it is nominated, the target is given a number and this information is added to the DTF. In order for a platform to launch an attack on this target, mensuration must have occurred in parallel with the above, or nearly so. Often a platform/workstation other than the one launching the missile will be most appropriate for the mensuration of the target, and mensuration can be done by several PTW workstations in an FBE so one or more operators may be adding mensuration to the DTF. The ANALYSIS chat area would be a viable resource for discussions of this process and an observer trained and dedicated to assessment of the handoff of data from sensor to mensuration to LAWS may find the ANALYSIS chat an area appropriate for feedback.

For example (hypothetically), Anzio, CSG and XVSSN all show target "GJ3092" in their system. XVSSN has the clearest shot at the target, but has no ability to mensurate the target due to their position or lack of direct access to a sensor. CSG has a UAV IVO the target in question and can mensurate for XVSSN. Often times a process like this occurs without a problem. However, it seems very common to have a situation where mensuration takes a long time or has problems due to various conditions. Examples of these sorts of conditions would seem to occur (hypothetically) when:

(a) CSG is having communication difficulties
(b) the UAV is down
(c) a workstation is busy or the operator is away from his/her station
(d) there is confusion about LAWS information
(e) there is a specific problem with LAWS
(f) a sensor isn't available
(g) there are discrepancies in target numbers

In situations such as the above the EQKMS knowledge workers are able to spot these problems during the coding process and mark them accordingly. As the EQKMS project has progressed, and the knowledge workers have become more fluent in the processes and terminology, an added benefit of this human intervention in the processing of the resources is the identification of missing elements or inconsistencies—such as the need for a more robust use of the ANALYSIS chat areas, suggestions for usage of this chat, and ideas for topics given missing elements in the available data. This form of high-level analysis is unique to the qualitative analysis process and would only be available with the use of knowledge workers trained in knowledge extraction, situation analysis, and the environmental and system variables common to an FBE.

Figure 20 contains a segment from FBE-G illustrating a series of questions. The process for posing such questions itself provides an interesting avenue for analysis and would be appropriate for assessment in the ANALYSIS chat. The recording of this information in the knowledge repository, under a number of search criteria, would be important. The mechanisms through which the answers were received, or lack thereof, would be an area of importance and unique to the types of analysis being conducted through EQKMS. This segment was tagged by an IJWA analyst as containing an interesting discourse appropriate for further assessment.

```
FILE: #TCT0404
[12:45] <LCDR_Burian>
      CSG/ANZ/LAS/JFACC/IKE..NEED ANSWER TO
      THE FOLLOWING QUESTIONS---FROM THE
      NWDC LEAD'S PRESPECTIVE...1.  DO YOU
      RCV UAV VIDEO/TELEMETRY.  IF SO,
      NUMBER OF CHANNELS    2.  DOES YOUR
      GISR PASS TGT NOM TO JTW?    3.  CAN
      YOU DO A MANUAL TGT NOM FROM GISR.
      4.  DOES GISR PROPAGATE TGTS TO EACH
      NODE FOR BIDDING?   5.  DOES A GISR
      TGT NOM INJECT A TRACK INTO THE COP?
      6.  DOES A TGT NOM FROM GISR POST AS
      A DIGITAL TGT FOLDER?   7.  DOES GISR
      PROVIDE A UNIT ID TO TGT NOMS?

[12:46] <LCDR_Burian> 8.  CAN YOUR GISR
      NOM A TGT FROM A UAV VIDEO FEED?
```

Figure 20. Partial IRC discourse through TCT with implications for ANALYSIS chat and post-FBE knowledge organization

There are also documents geared to the instruction and guidance of data collectors and analysts in relation to the collection of data in the FBE. For example, the file "analytic framework-FBE G - Rev II.doc" summarizes initiatives to be examined during FBE-G. It provides both top level and detailed questions of interest to support operational analysis of the results of the initiative. There are questions for analysts to utilize concerning the COP, C2 architecture, Methodology for Sensor-Weapon-Target Matching, TCT Sensor planning, loitering weapons, Submarine/Special Operations Forces and TCT target folders.

Another file in the Analysis Planning folder is "Electronic Data Collection in FBE G.doc". This file is directed at data collection and observation personnel onboard the platforms in the FBE. Specifically, what electronic information needed to be collected and how it was to be warehoused and transferred. "FBE-G Appendix D (draft rev 1).doc" contains useful information regarding the FBE, including: an overview of FBE-G, Experiment process, system methodologies, experiment coordination, concepts of interest, TCT analytic questions/data collection instruments, LAWS, GISRC-M, and PTW.

For post-experiment information searching and filtration, the data in these files does not serve as a key resource for target resolution and process issues. Although these files do point to some interesting questions regarding processes that have already been defined through rigid coding and search techniques within EQKMS, the actual data is not of benefit for information extraction. Rather, these files may prove useful in cross-referencing FBE search criteria once multiple FBEs are integrated into EQKMS. The collective of the FBE resources in the knowledge repository will bring a greater understanding of the overall picture of the experiment and the operational efficiencies of the IJWA analysis.

5.8 Data Sheets

The observer who authors the analysis in the data sheets is an experienced participant in FBE operations and is monitoring multiple facets of the experiment from a given platform. This is an indispensable data source for IJWA's in-depth qualitative analysis of the FBE. The observer is able to understand problems and issues that arise in various areas as opposed to the single operators that are monitored and coded within the IP Chat data—and who have a far less broad view of processes and problems. The addition of the observer data to IJWA's knowledge management system not only enhances search capabilities but fills in holes in the data that would be otherwise left unresolved.

For example, in the IP Chat engagement file for a particular date there is discussion of a civilian convoy being damaged in an attack. This was originally coded as a non-military target process issue since civilian damage is obviously not a desired outcome. But, with the addition of the data sheets and observation files a search reveals that an observer had noted the civilian damage as a misinterpretation of data. This finding led the IJWA analysts to go back to the process labeled as civilian damage in IP Chat and change the code to a misinterpretation of data rather than civilian damage. This process of misinterpreting data will also be reflected in the search output for the target in question. Thus, misunderstandings can be documented through the EQKMS search techniques and potentially embarrassing environmental variables corrected. Thus, the integration of qualitative and quantitative data sources across subject areas enables a greater understanding of critical areas.

Team analytic questions and answers are also an important part of the data sheets resource. With the integration of this data into EQKMS the IJWA analysts are empowered to extract some very crucial information and conceptual relationships. For example, in a typical IJWA analysis of a specific platform, the goal may be to extrapolate all targets that were engaged by that platform on a particular day in the FBE. If searching only the IP Chat data the search output may be nebulous due to the very large number of participants—all discussing many targets, some of which are not high priority, or on duplicate tracks, or are old or from test missions.

Issues such as the above will make for a large search output that will require further analysis to determine which targets, for example, were engaged by Anzio (given this was the original intent of the search). The team analytic questions/answers as an independent information resource in the knowledge base can be searched and checked against other information resources to resolve unanswered questions. A traditional search system may inadvertently filter key relationships. The EQKMS approach addresses data both independent of context and within context (fully integrated with all pertinent resources).

Another example would be search output that correlated 20 or more targets with a particular platform. After the integration of the data sheets, and analytic questions/answers resources, a parallel search was performed and the results crossed against the IP Chat data. A discovery was identified which might have passed through a non-comprehensive system. Specifically, the following passage appeared in the search output of a data sheet:

> Today's engagements totals 32 nominations with 3 ANZIO shots (all ERGM). Of 32 nominations, only 6 had imagery attached to the email. 12 resulted in dwell expiration, 1 expired due to friendly SOF in the area, 1 not high value, 15 lack of mensuration, and 3 shot.

A traditional search in chat would not output such specific summative information about the engagements undertaken by Anzio. The integration of this kind of data into the knowledge management system also makes identification processes issues easier for the analysts via parallel query techniques. Search procedures done only on chat data do not reveal the true complexity of an engagement. A more accurate picture emerges with parallel search procedures with multiple data sources, and the integration of quantitative and qualitative data.

Thus, the observers provide a perspective which helps correlate search techniques. Filtering processes derived from the combined data makes it much easier for IJWA analysts to understand where, when and how relevant engagements occurred and to document pertinent information flows and processes. This kind of understanding is unique to an integrated qualitative/quantitative analysis and to the EQKMS approach of searching against data and information resources—and then comparing and contrasting those searches and findings. Thus, EQKMS brings a new, higher level of analysis to FBEs.

The integration of this data is also very pertinent to the process issues that are being explored by IJWA. For example, if an IJWA analyst thinks, from their interpretation of the data, that there are likely too many people in the engagement chat and codes the file as such, then this assumption can be proven or disproven by the additional coding of the analytic questions/answers. Another example of the importance of cross-information searches can be shown by the IJWA coding of each mention of a communication link problem as a specific process. In so doing, IJWA has assumed that these communications difficulties are a problem to be noted and perhaps addressed as reflected in the target resolution process.

Once the data sheet information is coded and integrated, IJWA can ascertain whether the team analytic Q&A is viable. For example, if the observer states that the comms were down 34% of the time on a particular day, then this information will allow IJWA analysts to not only verify the problem with communications through normal analysis, but also through correlation to the team analytic report to determine exactly how long the comms were inoperable in a given FBE. Thus, when IJWA searches processes associated with communications difficulties the output will produce each segment of data where comms issues were occurring in realtime via the chat files and also the team analytic report of exactly what percent of the time the comms were down.

The above process of cross-information clarification/verification is also useful in the defining of different processes identified as important. For example, the following data segment from the team analytic Q&A verifies a process that was common throughout FBE-G chat.

> A major shortcoming from the experiment is the lack of COP input into the GISR picture. It is very difficult (not practical) for GISR operator and GCCS operators to look at both systems and attempt to correlate tracks and sensor data via the two screens.

The above is a reoccurring issue within FBE-G that was identified by IJWA analysts when coding the chat files, and further supported when integrating the data sheets and observations information into the knowledge base.

Additionally, summaries given by the observers in the analytic Q&A are helpful to show differences in the engagements from day to day throughout the experiment. For example, if communications were really detrimental during the first two days of the FBE, then improved on subsequent days, then this will be noted in the overall picture and reflected in the coding. With less than comprehensive and integrated qualitative/quantitative analysis such facts may not have been as easily extrapolated from the KM system. Such processes will enhance the understanding of the FBE as a whole.

In the collective, the addition of comprehensive, multi-perspective data will be a key component enabling IJWA to completely utilize the "drill-down" capabilities possible in EQKMS. For example, the Data Sheet information differs from the Golf IRC data since it is observational in nature rather than a log of realtime, dynamic discussions. Items coded would include the flow of information through the various systems, the dynamics of the joint interactions involved in the FBE, the use of sensors, and the processes and means of TCSF resolution. This will enable IJWA to resolve several issues, including the tracing of targets to their original sensor event, while providing needed insight on process issues that hinder the efficiency of a given FBE system.

The above categories of events, as noted by the observers, are representative of the types of data that can be extracted from EQKMS for a comprehensive analysis of an experiment. There are elements of operational matters in an engagement included in the observers analysis, notes regarding the effectiveness of the techniques used, target specific observations, sensor specific observations, system specific observations, system operator notes, communications systems activities, and general process and procedure observations.

At a more practical level, the tracing of target numbers to sensor events is one of the more challenging tasks faced by the IJWA EQKMS team. The primary means to match a target number to a sensor event is for the analyst to look back and forth between the Engagement chat and the Targets-Sensors chat and correlate these with the LAWS data. With this technique, the analyst uses time as a reference point to recognize sensor events in Targets-Sensors that match the target number being discussed in Engagement. The target specific observation data in the Data Sheets information is another means to link target numbers to their original point of detection by sensors to determine the overall target identification and resolution sequence. Thus, an additional verification mechanism.

Target numbers and their corresponding sensor events can be filtered through various coding and searching techniques. When a sensor event is noted in the Data Sheet files it can be tagged with the target number. Then, when IJWA analysts conduct searches on specific target numbers not only will the data segments that have the target number be filtered but so will the pre-target number sensor events that have been tagged with the target number.

IJWA analysis can thereby address recurring problems that impact the efficiency of the Battle Group. Qualitative analysis is important because problems are not always discussed in the context of an actual problem but rather are inferred by the type of discussion going on in relation to the situation. Examples of such situations include: misunderstandings; misinterpretations of data; system or communications malfunctions; sensor allocation problems; missile guidance problems; and target mensuration problems. We have defined these types of problems as "processes" and there are ten different processes that have been defined within the IJWA EQKMS. These are discussed later in this section.

5.9 LAWS

The LAWS qualitative resources are concerned with the usage and effectiveness of the LAWS system in the FBE. The information in this resource serves as a cross-search key for information in the knowledge repository. The data is pertinent for searches that deal with process issues and to fill some of the "information gaps" in the tracing of target resolution times. For example, searching for specific target resolution times within IP-Chat can be difficult due to many different problems. A cross-key search to LAWS data can often resolve the matter.

An example of a problem in FBE-G was when the LAWS systems have multiple mission numbers for one target. This fact can be difficult for the analyst to determine just from the data available in IP-Chat. The addition of the LAWS information to the knowledge base provides a search resource wherein mission number processes can be noted, coded and correlated to specific events. Thus, the analysts can use the LAWS data collector's information to verify that multiple mission numbers for single targets was an issue on the day in question and can integrate this knowledge into their analysis.

Another problem that surfaces often within the FBE is block colors not changing appropriately. There were many data segments in IP-Chat that show problems at the LAWS stations for the operators concerning the command block and the mission nominator blocks colors being wrong and/or changing frequently. This kind of problem is noted by the LAWS data collectors and a data collector may also offer suggestions for fixing the problem or explanations for the cause of the problem. This kind of data would not be available to analysts without the addition of these files to the EQKMS, and the relevant issues could not be as fully addressed in the final analysis.

For example, the file titled "IKE data logs4040506.doc" is a summary of LAWS issues noted by the LAWS data collector for the dates of April 5th, 6th, and 7th. Below are samples of data segments from this file that would prove beneficial to high-level search topics involved with the use of the LAWS system, as well as lower-level searches on LAWS data for specific days in the FBE.

> Confusion at the beginning of the day as to who had control over firing units because command blocks were being turned green, however, this was due to the fact that JFMCC (IKE) had receiving capability but no transmit capability. (IKE data logs4040506.doc)

> Much confusion running missions. Anzio fired TLAM without a route and while CMD block was white and WRD block was also white. CTF 69 fired on a SCUD B with TGT block red and CMD yellow. No missions were run entirely through the system. All missions were injected by MTO. Not much sensor coordination. Chat sessions not utilized properly. A lot of discussion of engagement issues in the TCT_CMD chat session. Voice was used more than it should have been partially due to the fact that was the only way IKE could communicate to the outside world. (IKE data logs4040506.doc)

The information provided in the passages above would not be easily ascertainable from a typical information system but can be easily extracted from the EQKMS through the knowledge hierarchies. This is due to the advanced cross file, cross project, cross FBE search and filtration capabilities of EQKMS. Data segments, like the examples above, will prove to be an important part of the knowledge base for FBE analysis in relation to the LAWS system. The easy access of important data segments like the above will also be key to high-level FBE analysis and can be used to track the usage and effectiveness of the Land Attack Warfare System throughout FBEs. Thus, LAWS qualitative data gives the analysts a much clearer picture of the events in a particular engagement—especially as they pertain to LAWS information regarding the process of target resolution.

Another example is the "IKE observer report0329-0407.doc" file that contains information about the LAWS system such as: actions completed, PC configuration and LAWS software installation, installation of map data (LAWS), clearing the SMTP outbox (LAWS), installing the mIRC chat, and basic LAWS training with other shipriders. As stated below, there are specific cause and effect type problems that can be defined by an EQKMS cross-reference to the observer/data collector information:

> The LAWS operators are having a difficult time performing their jobs because of so much information being passed over the LAWS terminal that strictly speaking does not concern LAWS operation. The exercise is using chat windows and VAT for internet voice communications and both of these are located on the LAWS terminal. The battle officer for LAWS1 (JFMCC) is using the LAWS keyboard/mouse and terminals more for monitoring the comms than for operating LAWS. (IKE observer report0329-0407.doc)

This kind of information is based on insight from an experienced observer in the FBE and contains data that would be otherwise difficult to include in an analysis. The inclusion of these files into the EQKMS will enable an easy access and retrieval of the key data and concepts. The integration of this information into the knowledge base will enable a higher level of analysis.

"JFACC 4 5.doc" is a JFACC LAWS observer log from April 5th. Topics summarized in this file include: multiple mission numbers for one target; WRD column not being used; Unit ID mismatch; notice of target modification; Mission Manager Nominator block is not accurate, and concerns that the track numbers on GISRS do not match up with LAWS track numbers; and concerns that not all units are entering the GCCS data according to the CONOPS. Here again is another file that will bring the same benefits already discussed to the overall understanding of the FBE (high and low level) and add to the search results from EQKMS. One of the unique features of this resource is that it highlights LAWS actions listed by time. The fact that events are time quantified means they will be easier to correlate to FBE engagement operations for the specific day in question.

5.10 Sensor Management

The "Sensor Management" resource contains files that have data concerning lessons learned, recommendations, and observations done during the course of the FBE. Added to the EQKMS, this data resource supports those analysts looking at sensor processes as well as engagement issues or high-level cross-FBE searching.

For example, the data in the file "Observations for GISRC - LAS.doc" is inclusive of the observers hardware/software recommendations for improving the GISRC system, suggestions for better sensor usage and allocation, discussion of communications usage between sensor operators, DTFs, situational awareness (COP), IRC usage and GISRC/LAWS map features. This data will be coded as recommendations and observation within the EQKMS. This coding scheme will allow for cross-file searching in order to bring together all of the many data segments that include recommendations. These types of recommendations need to be coded, categorized, and warehoused for further detailed analysis. Doing this in the EQKMS allows for easy availability and retrieval of this newly categorized information.

Another example is the file "FBE-G GISRC-QL-Final.doc" which is an executive summary of lessons learned through observation analysis. Main sections in this document include: JTF Sensor Planning/Management; ISR Anchor Desk Screen Layout; Offensive and defensive Battle Watch Captains; decentralized, network centric functional architecture; ISR-T screening processes; Target Block numbering; Multiple Target Keys; Digital Target Folders; UAV, ELINT, & MTI; LAWS mission nominations; Distributed mensuration distribution, Tactical UAV control; and digital video telemetry. There are detailed summaries including recommendations for each of these topics.

With the integration of the above file into the EQKMS the analysts will be able to search observation summaries that are related to nearly every process involved in the FBE. This data will be especially helpful for the sensor issues that are being researched. This data can be used for cross-search techniques when researching other topics within the FBE.

5.11 Process Descriptors

When the EQKMS project was first undertaken the focus was to trace target numbers across the knowledge repository and extract data relevant to the identification and resolution of targets. However, once the IJWA analysts started reading and coding the data it became apparent that there were problems that had a significant effect on the FBE. These problems were occurring too often to be ignored and were relevant to the overall effectiveness of the FBE. So, these problems were defined as "processes" and a coding scheme was created to deal with these processes and defined within the EQKMS codebook. The inclusion of "process" tagging within EQKMS was initiated by the knowledge workers reviewing the qualitative information and the coding is consistent with the high-level analysis issues established in Figure 2.

```
SEARCH: PROCESS-1
SEARCH CODES:
#-PROBLEM #-TRACK_PROB T#GJ0015 #-PROCESS-1
FILE: #COP0407

[09:52] <COPCI> so, can we find out who
        entered gj0015??
[09:53] <COPCI-trk> right...but it was a
        trk...should've been a unit...there
        was also another one already done
        correctly
[09:54] <COPCI> okay, pls try to find
        out who input gj0015...i'd like to
        highlight that later today as a
        mistake...
```

Figure 21. Partial IRC discourse tagged as Process-1.

As a result of this inclusion, IJWA analysts can now search different types of processes and filter by the frequency of occurrence of a specific process. "Processes" generally revolve about issues that affect the dynamics and effectiveness of an FBE system. Examples of problems include: misunderstandings; misinterpretations of data; system or communications malfunctions; sensor allocation problems; missile guidance problems; and target mensuration problems. The identified processes are as follows:

<u>Process-1</u> : Target identification or launch sequence problems, concerning matters such as: (a) who should take the target, (b) interpretation of rules of engagement, (c) conflicting commands, (d) trouble receiving target mensuration data, (e) target folder establishment or transmission, (f) box identification or transmission, (g) insufficient firing data, (h) incorrect color code of target. See Figure 21.

<u>Process-2</u> : The process of upgrading or troubleshooting software, hardware, systems or sensory equipment. Or, walking operators through a troubleshooting session. See Figure 22.

```
SEARCH: PROCESS-2
FILE: #FB0401
[16:27] <Burian> GIRSC5: WHAT'S YOUR
        ESTIMATE OF BEING OPERATIONAL?
[16:27] <ANZ_gisrc9> this may take a
        couple paragraphss.
[16:29] <GISRC5> Burian - I need to
        download ERM software yet.  anzio
        is helping right now. would love to
        be done this evening.  Still have a
        few TASID install check to make
[16:29] <ANZ_gisrc9> you need
        GISRC7\d\fbe-g_setup\erm.zip and
        ERMUpdateforPC.zip and
        ERMUpdate0326.zip
```

Figure 22. Partial IRC discourse tagged as Process-2.

<u>Process-3</u> : A loss of time or time inefficiency due to a deviation in a computer, communication or sensor system.

<u>Process-4</u> : Personnel misunderstanding or a misunderstanding concerning the interpretation of incoming data from one or more systems, or the misreading of data on a system, or problems with the input of data, or inconsistencies with the source of the data (e.g., target data). For example, in the following passage there is some confusion as to which system is designating a target:

[12:49] <COPCI-trk> anything beginning with GG, GJ, GA, LS, LA is from laws
[12:50] <COPCI> no, there from gisrs, and there is no mensuration as yet....
[12:54] <COPCI-trk> if it is in GCCS, with those digraphs, it came from LAWS
[13:07] <COPCI> that's not what i was told

<u>Process-5</u> : A referral of an information source (personnel) to another chat for further discussion based on an identified topic and the appropriate continuance of that topic in that chat

area. The process issue under investigation would generally involve the synchronization and consistency of the topic or target referrals for continued action or analysis. An example would be as follows:

[10:50] <COPCI-trk> grnd: when you get of interest elint (like what you've been passing) make sure it goes out of the Targets-Sensors channel.
[13:40] <LCDR_Burian> IKE, REQ YOU COME UP IN #TCT_LEAD

<u>Process-6</u> : A system or human-system target identification issue such that a target has been improperly read or numbered by a system or operator, or there is a deviation between numbers and targets, or different numbers have been assigned to the same targets.

[12:35] <COPCI-trk> jfacc - GJ4037 is the same as GJ4036 and 4036 is what was nominated....do not enter 4037
[12:50] <COPCI-trk> naval - can you start associating some of the elint to the trks
[12:59] <COPCI-trk> nevermind....they won't assoc
[13:00] <COPCI-trk> one is real world, the other is live-trng...can't assoc the 2
[13:30] <jfac-gccs> copci-trk: I don't hold 4037 in my system (I recall entering 4036)
[13:31] <COPCI-trk> rgr....sorry about that....turns out it was anzio entering the wrong tgt number

<u>Process-7</u> : Target action with missing or incomplete data and significant discussion based on this issue or associated/supporting data processes.

<u>Process-8</u> : Command or command structure procedures regarding targeting and delivery, such as: (a) the assignment of a target, (b) commands to remove target given varying commanders and launch operatives, (c) confusion over whether or not a target is approved and a green has been given, (d) confusion over firing processes concerning target priority/ assignment. See Figure 23.

<u>Process-9</u> : Battle Damage Assessment indicating that the target destroyed may not coincide with the target initially identified, or that it is a civilian target.

<u>Process-10</u> : Problems concerning missles such as: (a) the guidance and control of munitions once in route, (b) problems viewing the status of a missile, (c) confusion over how many missles have been fired at a target.

In sum, the above manner of qualitative analysis requires skilled knowledge workers, and analysts with an understanding of the technical and environmental variables in play during an

```
SEARCH: PROCESS-8
FILE: #EN0407
[09:48] <C6F-STRIKE> JFMCC-I show no
        green cmd light on 69 but they
        fired anyway.
[09:49] <IKE_JFMCC> rgr C6f, thought
        that was what we heard last night.
        Will enforce
[09:49] <JFACC-ISR> ctf69_laws: are you
        saying sub has launched mls against
        0051?
[09:49] <XVSSN> c6f-strike, we cannot
        mensurate. only tgts we recieve is
        via laws
[09:49] <ctf69_laws> unable to launch
        gi1570 due to rte conflict. canco
        with grn cmd
[09:49] <XVSSN> and we have assumed that
        this is mensurated data
[09:49] <JFACC-ISR> correction:  0015
[09:50] <ctf69_laws> jfacc- no.  launch
        on gj0015 not 0051
[09:50] <IKE_JFMCC> rgr ctf 69. I can
        not canx the grn. understand you
        can not fire
[09:50] <IKE_JFMCC> box probs
```

Figure 23. Partial IRC discourse tagged as Process-8.

FBE. The search on processes is a major attribute of EQKMS and files are being routinely coded for process issues. A query on a particular process will reveal the transactions surrounding the occurrence of the item in question, relevant tags to any associated targets, the operators involved in the discourse, and the time period in which the exchange occurred.

6.0 EQKMS Processes and Functionality

The EQKMS was designed for high level analysis focused on effectiveness issues in FBEs. The generated search information supports IJWA analysis of an FBE and the comparison of attributes across different FBEs. An example would be suggestions for software or hardware changes, bandwidth upgrades, and C2 changes—which when coded and addressed within EQKMS—can provide cross-area or cross-FBE needs analysis. With the addition of data from future and past FBEs an overall picture of systems effectiveness can be derived.

EQKMS is being designed to facilitate the extraction of both high level issues (e.g., recurring process/problems throughout multiple FBEs) and more specific items (e.g., FBE specific, time specific, target specific, etc.) which are classified as lower or operational level—such as dynamic processes captured in realtime. The ability to "drill-down" from decisions to event data, or from events to decisions, requires a flexible methodology in both the setup of the system and in the data categorization. A systematic approach of data collection, management, filtration and analysis makes EQKMS viable for high and low level analysis. An example of a high level systems classification in EQKMS would be data segments such as the following:

> A bandwidth management capability is necessary for TCT prosecution with multiple sensors in a Strike Cell architecture, particularly if migrated from a shore reachback environment. With close monitoring with the Packeteer tool, Strike Cell came close to a bandwidth limit, where they might have to decide between further aimpoint mensuration or additional imagery data, but did not need to dynamically reallocate any bandwidth. If the architecture moved to multiple radars to provide overlapping coverage in baffle areas during aircraft turns, or to provide independent views of both Spot Hi-Res SAR and SAR/MTI, a recommended capability, then bandwidth would have been much more of an issue. This is especially true if automated filtering tools were not available. Also, if multiple UAVs or aircraft were reporting back to the same Strike Cell, bandwidth for aimpoint mensuration would have been an issue. If the Strike Cell is moved to a naval platform (CG, SSGN, aircraft) this would also be an issue to ensure this tool were available to support changes in the dynamics of the TCT prosecution timeline from a sensor intensive period, to an aimpoint generation focused operation. (source: FBE-G_Conus_Quicklook.doc)

The data segment above is a suggestion, by an observer, that relates to the resolution of a process problem that has already been identified and tagged within EQKMS by an IJWA analyst. An example of low-level analysis would be the tracing of a target from initial sensor reading to conclusion, or the identification of a specific communication problem, for example, concerning time latency in receiving mensuration data. EQKMS allows for the warehousing of all this knowledge as well as the search, retrieval and extraction of such information. It will be possible through EQKMS to extract not only each occurrence of a discussed low-level problem but also provide any available high-level analysis which supports the issue under assessment.

The integration of high and low level information, and qualitative and quantitative data, brings a higher level of understanding to FBE operational issues. When such analysis is coupled with data from other FBEs, the collective enables the analyst to see if a process or problem is occurring across FBEs—and to see if any suggestions have been made to fix the problem(s). In a situation in which suggestions are being made but not enacted (i.e., these problems keep recurring throughout various FBEs) then an EQKMS search of the repository can help support the solution.

Another example of the benefit of data repository analysis through EQKMS is the potential it offers to bridge the gap between software designers and users. It is possible that the needs of the military operators are not being met by the designers of the software being used in an FBE. In other words, when suggestions have been made concerning upgrades to an interface or the improvement of operational components of software critical to TCT operations then an EQKMS search of the available resources can document systems or software issues. An example may be found in the following passage, which focuses on the need for more automated data insertion to improve the COPs effectiveness:

> TCT prosecution requires more automated insertion of data and fusion of data into information that can be displayed on a COP. The current processes and tools are too MMI intensive. High resolution SAR, once downlinked from the aircraft, either directly to a reachback strike cell, or through a battleforce network node (e.g. DD, CG), must be available to provide situational awareness or target validation on a faster timeline. The SAR is most valuable in prosecuting TCTs if it is directly injected into the COP (if relevant), or rejected by an automatic FOTC-tool that could eliminate images that do not meet certain relevancy criteria. MTI in isolation was not useful without additional cueing. (There appear to be an analogy with Active SONAR in the ASW methodology that we had not considered, such that MTI is best used after initial classification of target if interest.)
>
> Range of system operation made it difficult to detect moving targets, and specifically convoy formations, in part also due to shadowing from treelines. The image manipulation process was too cumbersome and manually intensive. To some extent, there were too many Strike Cell workstations working the problem, such that the decision-maker would settle on an operator/display combination that provided a comfort level, as opposed to a managed or self-synchronized organization. Use of chat was cumbersome when used for data manipulation, such as passing Lat/Long data for cross-cueing of sensors. This COP also needs to be a dedicated command display that is shared by all manned stations on the aircraft as well as at Strike Cell. This display capability was supposed to be outfitted on the aircraft, software applications for common displays did not make it for integration. At Strike Cell, one monitor was hooked up to a large vertical display for the watchsection and a Commander's Display. It is important that the GCCS-COP manager/operator function be a separate display, so that menu operations do not obscure the CDR's view with dialogue windows.

> A capability that includes SIPRNET to the aircraft for a COP and IRC chat would be helpful. A video link of aircraft displays was available over the TCDL at the Ship Ground Station, but not directly to the Strike Cell, yet this capability we believe would have assisted Strike Cell greatly. The common displays function, that provides each aircraft station with a dual monitor and allows selection of a COP at each station would have reduced verbal and written communications, and probably reduced turnaround time for SAR requests significantly. This would also overcome the problem with different systems using different data formats for position information, which was unwieldy when trying to cross-correlate. There was strong desire for a "whiteboard" collaboration capability, that would allow the decision-maker, such as a Strike Cell ISR Action Team, to designate on a screen collection requests for upcoming aircraft passes (a la John Madden). A GBS capability should be explored as part of the architecture." (FBE-G_Conus_Quicklook.doc)

Analysis of the passage above should lead to solutions that will improve the overall operations of the FBE. But, if such analysis is not being used to correct the issues, then this data should be made available to persons who will authorize the necessary changes—but also communicated to the software engineers and operational personnel that will implement these changes. In reality, the process is often more complicated as the communication of such needs is too often obscured by the difference in understanding between the programmers of the software and the users/operators of the software. EQKMS analysis can help by providing a bridge between the qualitative and quantitative, and a resource to categorize and classify situational and process problems. If data analysis—similar to the above passage—is available upon request it can be used to help bridge some of the communication gaps between operators and software developers, and thereby help resolve the problems that need to be addressed.

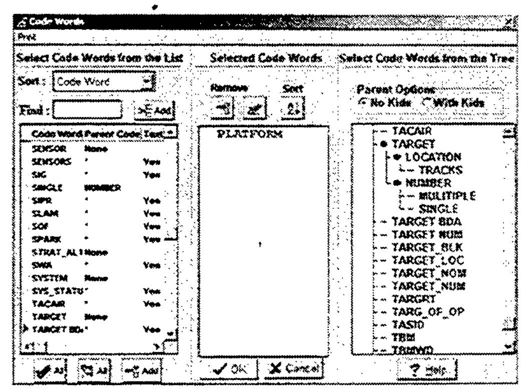

Figure 24. EQKMS implementation of coding structure to FBE-G information and data resources.

6.1 Phase 1 Interface and Operations

EQKMS is still in the very early stages of development. The midterm objective is to provide a means to classify and categorize qualitative information, and to then link this information to the quantitative data. The knowledge hierarchies discussed earlier are a mean to structure the data, and the code words [as identified earlier] are a means to provide drill-up and drill-down capabilities. Both the code words and the knowledge hierarchies can be seen as they are applied through the code trees in Figure 24. The knowledge hierarchies are the prominent means to structure information in the repository, and together with the code words, to filter and search for information in the EQKMS Phase 1 knowledge operations.

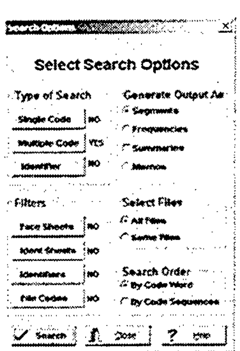

Figure 25. EQKMS search and filtering options.

The EQKMS phase 1 methodology utilizes qualitative analysis software to tag and code sentences and phrases in chat, interview, observation and reference documents. The knowledge managers structure relationships in the files and then perform single, multiple or filtered searches based on the code words and/or the identifiers, and/ or the search filters (Figure 25). The identifiers and the filters utilize the key category labels specified in the knowledge hierarchies. The search trees and code word identification structures are generally hierarchical, but the searches pull from across files—somewhat in the style of a relational query. The searches reference the subject data and produce a thread which links the search result back to the original file for additional analysis. This capability is also the basis of the drill-down and drill-up functionality from decisions to events and vice-versa. Complex searches for multidimensional relationships is supported in EQKMS. This would include:

a) cross-file searches, for example, from sensor to target to decision to engagement
b) searches for variables in decision processes keyed to time and operator actions
c) delineation of system and technical variables in the TCSF identification and engagement stream
d) multi-tier searches for specific targets and associated processes
e) correlation by the number of occurrences of a particular target, track, or sensor reading
f) any combination of time variables in target identification, engagement, or assessment
g) linkages to target occurrences across the repository, keyed to time or other variables

6.2 Quantitative Analysis of Qualitative Data

Various systems are available to manage qualitative and quantitative data. However, these systems have historically operated independently—with traditional quantitative data processed through transaction systems, and the supporting qualitative information available only through an examination of the notes, memoranda, letters, videoconferences, observations and reports existing on various desktop machines and servers throughout an organization. Quantitative information has a history of consolidation, while methods to track and utilize the various forms of qualitative data are only beginning to emerge. The linking of the qualitative with the quantitative is an even newer endeavor and the tools and approaches are still relatively developmental.

In the military, the knowledge management process is several levels of magnitude more complex than the commercial sector—for the reasons mentioned above, but also due to the amount of quantitative and qualitative information which is being generated. A corporation typically has a central transaction processing repository and a data warehouse. The military has dozens of transaction systems in operation during an engagement and these specialized machines generate quantitative data in various formats—and this variety does not permit an easy integration.

The qualitative processes are similarly complex, with various personnel providing varying levels of perspective on each of the quantitative systems, and on the interplay between the systems and their human operators. Also to be addressed are the effects of varying interpretations and actions based on the data, results of human-human interchanges concerning the data, and the impact of new variables in dynamic situations. Corporate decisions, by comparison, occur in a relative static environment and the analysis necessary for strategy refinement has the luxury of an extended time frame. However, in the military, the competitive forces to be addressed may be changing every few moments, and the strategies in play far more complex and dynamic.

The integration of qualitative and quantitative (Q&Q) analysis provides both the data used to make decisions and rationale and understanding of the decision processes. The quantitative data is the information that flows through the various electronic hardware systems. This data is in support of the C2 timelines. The primary systems include:

• LAWS	• PTW	• COP	• STOW
• GISRS	• GCCS	• JSCE	

These systems provide the core quantitative data for analysis. The supporting qualitative data would contain human-in-the-loop actions within each operation and across operations—including decision-making processes, point-in-time assessment of the systems, etc. In addition, within each of these systems are processes that are part of decision making. For example, mensuration often requires the use of reference imagery. An operator access of the reference image library becomes an event that can be recorded—not only the time that particular type of event occurred, but also what type of data was pulled. Qualitative analysis would reveal how that data was used and the final outcome of the application.

Synthetic variables can be introduced to help ascertain likely interactions between qualitative decisions and quantitative data. For example, information injects from STOW can initiate trains of events which would generate understandings from the quantitative data and the qualitative decision-making processes. An understanding of the linkage of qualitative and quantitative data is at the core of the IJWA KM efforts. The EQKMS Phase 1 capacity to establish the relationships between the type of data and the collection and assessment mechanisms is illustrated in Figure 26.

	Quantitative	**Qualitative**
Computer-based data generation/capture	Information flows within and between electronic systems	Analysis of human-in-the-loop actions with electronic data
External and time-critical events	Sensor readings, mensuration data, targeting information	Expert observer logging data Expert analysis of electronic events Expert guidance in decision processes
System and process performance		Post-experiment interviews with operators Expert observation of human-machine interaction Web-site comments Analysis of recorded coms from the operation Post-experiment workshops Analysis of event data

Figure 26. Qualitative and quantitative resources.

Event, system and process performance information can be captured and made available through knowledge management processes that integrate qualitative information with quantitative data. A crucial part of this process may involve quality assurance procedures—such as the analysis of LAWS data to reveal misconceptions about the performance of TCT processes. KM efforts in IJWA have focused on TCT processes in the initial efforts.

A first stage in the integration of quantitative and qualitative data has involved the analysis and synthesis of targeting events. Constructing TCT timelines is a difficult process because much of the needed electronic data has not been captured. In the present system(s) the following data sources are being synthesized in order to recreate TCT timelines and associated events and decision processes:

- Recorded LAWS data
- Recorded IRC Chat sessions
- Observer data logs
- Data sheets
- Post-experiment interviews
- Reference/technical documentation

A primary issue is that the LAWS data is incomplete and the IP Chat sessions are commonly offset in time because of the mechanics of participating in chat. Other issues are that the observer logs record data at only a few of the many locations. However, when the collective of this data and information is integrated into the KM system an accurate data stream or observation can potentially be used to correct chat time offsets or missing observer remarks. Intensive comparison of the data and information sources can enable the reconstruction of a few of the TCT timelines. This is a primary benefit of the initial IJWA knowledge management efforts to integrate qualitative and quantitative data.

It is important to note the crucial role that synthesis by the human analyst plays in this process. The first cut of synthesis results is to take the system and process performance information noted above, place it in categories (the beginning of synthesis), and extract information in which there is some confidence. This is the basis of knowledge management that interfaces quantitative data with qualitative information about that data. EQKMS is a project within IJWA that is actively conducting this integration.

In addition, EQKMS qualitative search results can be measured quantitatively. Search results on a specific target, system, process, decision, or communication issue (for example) can be counted to provide a hard measure of the number of occurrences of a given event, a specific situation, or a result. Complex or multidimensional queries can be similarly quantified to provide an objective assessment of the scope of the matter under consideration.

Figure 27 illustrates a native capability of EQKMS for conducting quantitative analysis of qualitative data. Specifically, there are internal mechanisms which register the number of occurrences of a specific search criteria, the prevalence or length of relevant passages of a given occurrence within the repository, and occurrences of events or decisions by file number and location to support drill-down and drill-up assessments. The system also supports traditional quantitative measures, such as the number of hits and frequency of hits.

6.3 Phase 2 and Future Development

The expansion of the knowledge base, linkages to additional qualitative and quantitative data sources, and more sophisticated search and retrieval capabilities using artificial intelligence are all EQKMS enhancements in current development. Mechanisms to automate the processing operations are also in development. Figure 28 depicts the current evolutionary path in which the core EQKMS model links qualitative information from various sources and applies organization methodologies and coding structures to the data to support information extraction. The categorization schema and processing methodology will support information in a variety of formats, and potentially, in various locations.

In development are methods to more tightly integrate the output from quantitative systems with the supporting qualitative information which provides perspective, rationale and justification for the event data. This is illustrated in the figure as a linkage into relational and object databases through Java, SQL or other search and processing techniques. This may most rapidly occur as linkages into reports generated from the various systems—and eventually as automated processing between systems. In the more advanced stages of design are methods to load data into the XML data object model for web-based reporting, and the use of agents and neural nets as a means to automate the processing, filtering and searching operations.

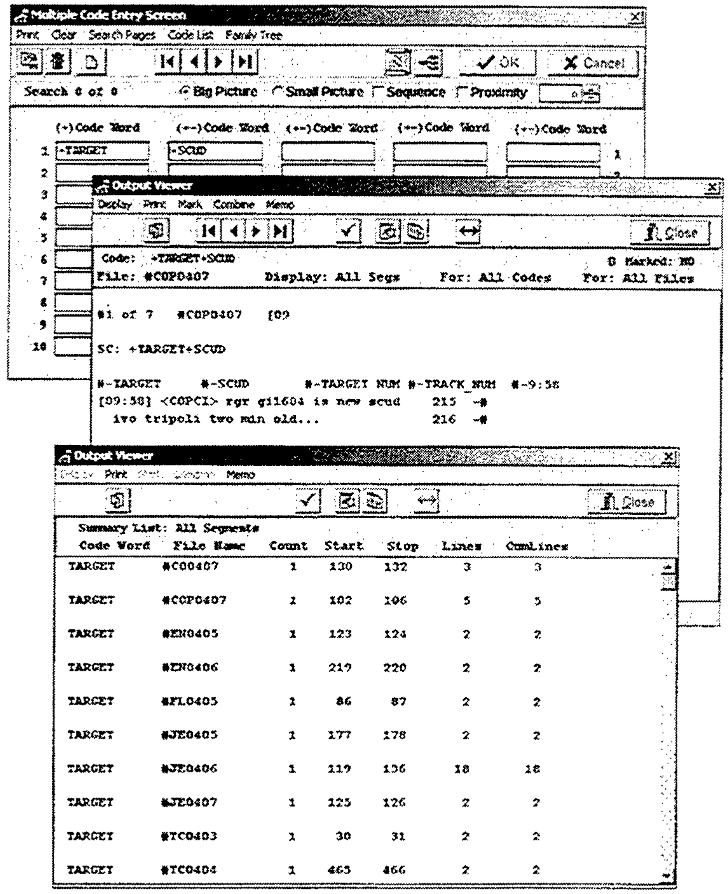

Figure 27. Complex search and filtering relationships and quantitative analysis of qualitative findings.

Figure 29 illustrates the logical extension of the system and methodology to include a manner of virtual knowledge and intelligence. This may occur as the information summaries, reports, and analysis utilize object-oriented and agent technologies to support distributed queries and information dissemination. In this scenario, through the use of advanced information processing tools, the data and information resources can be assembled, categorized, searched, and the results correlated with ever-greater speed. Ideally, this may one day provide analysis that supports a very rapid inclusion of all pertinent information resources and a very rapid dissemination of results. For example, the sensor systems presently support a very rapid transfer of information from the technology to the decision makers. The potential exists for qualitative information to one day support the operational data to provide expert opinion, historical perspective, pertinent references, results from similar situations, or actions and responses from related environments. Such capabilities would be the logical extension of the technologies and methodolo-

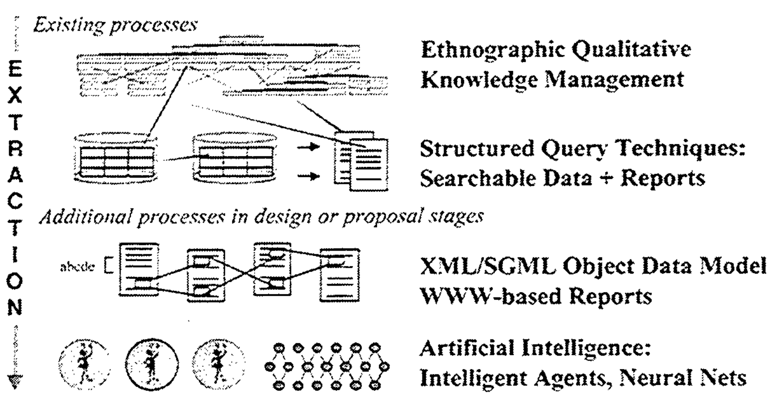

Figure 28. Evolution of EQKMS to incorporate agents and neural nets.

gies advanced in the IJWA EQKMS project.

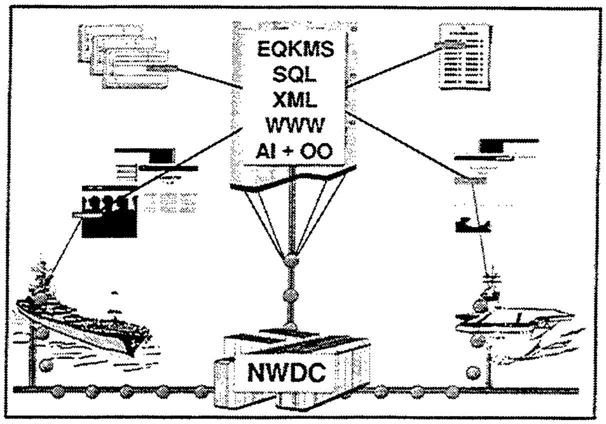

Figure 29. Evolution of EQKMS to provide dynamic, distributed, virtual knowledge.

Through the KM processes described above the analysis process can both expand to include far more data and thereby increased efficiency, while simultaneously increasing the speed with which the analysis occurs. Similarly, the distribution of the analysis reaches key decision makers within months or even weeks—which is very rapid for the scope and extent of the operations. As the EQKMS project expands, it would be possible to shorten the time period for analysis, while also increasing the scope of the distribution of the analysis. A possible objective would be to provide decision-makers with expert analysis soon after an FDE, and potentially while an FBE is in play or even when a specific operation is being conducted.

7.0 Conclusion

Qualitative analysis finds information not available in quantitative data, including objective perspectives, first-person accounts, decision processes and influencing variables. When integrated with quantitative data the qualitative sources enable a tracking of decision processes—from events to decisions and back again. A comprehensive knowledge resource, supporting both centralized and distributed information resources, will enable a higher level of analysis than has previously been available. The IJWA EQKMS project will support various searches and inquiries and produce not only the event but decisions resulting from the event and the thread back to the source data.

A key output of the system will be analysis to support improved decision-making processes. An example discussed herein was improved decision-making based on the accumulated experiences of peers in similar situations or experiencing similar events, e.g., decision processes in fires, data flows in critical systems; and measures of frequency of occurrence in selected environments. The systems would support the identification of possible problem scenarios and likely outcomes based on past occurrences, or projections based on similar situations. The analysis processes will produce measurable relationships between electronic data and associated observations, e.g., human-in-the-loop operations at specific nodes.

A key facet of integrated qualitative and quantitative analysis is multilevel reporting which provides a "drill-down" from high-level conclusions to supporting information; a "drill-up" from events to situations or decisions resulting from those events; and channels for synthesis to higher level decision-making criteria and processes. The integration of opinions and data into the analysis can produce statements and results about the status of an initiative or experiment outcomes—as well as quantitative measures of the qualitative results.

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